MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY OF
PARTS OF
NORTH LINCOLNSHIRE
AND SOUTH YORKSHIRE.

(EXPLANATION OF SHEET 86.)

BY

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PREFACE.

The Map described in the following pages (Sheet 86) includes the southern portion of the Yorkshire Lias and Oolites, and the northern extension of those of Lincolnshire, together with the underlying Keuper Marls and overlying Neocomian and Cretaceous rocks. Much of the ground is covered with Glacial Drift and Alluvial Deposits.

The northern part of the area embraced by the Map (Yorkshire) has already been described in two Survey Memoirs: "The Geology of the Country between York and Hull," by J. R. Dakyns, C. Fox-Strangways, and A. C. G. Cameron, 1886; and "The Geology of Holderness," by C. Reid, 1885. The descriptions of the rocks in that tract of country are consequently not given in detail in the present work, except in the case of the Drifts of Kelsey Hill, which are of special interest.

Within the area embraced by the Map nothing lower than the Keuper division has with certainty been recorded from evidence furnished by bore-holes. The Rhætic Beds are almost entirely concealed beneath superficial accumulations.

The Lower Lias yields a rich bed of ironstone, 20 to 30 feet thick, known as the "Frodingham Ironstone," but it affords no important limestones such as are usually met with at the base of the formation in other localities in the Midland and S.W. counties. To make up for thsi deficiency, however, the Lincolnshire Limestone at Kirton-in-Lindsey yields hydraulic limestones, which are

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worked in that neighbourhood for the production of so-called "Blue Lias Lime." It has been found desirable to make a local separation of these strata, under the name of Kirton Beds, from the more oolitic limestones that overlie them, here described as Hibaldstow Beds.

An important stratigraphical fact in the region is the unconformable transgression of the upper part of the Cretaceous Series across the older rocks, the strike of the Jurassic Beds being nearly north and south, while that of the Chalk is from S.S.E. to N.N.W. The Lower Cretaceous Series is a continuation of that in Sheet 83, but it thins out, or is overlapped, by the Chalk near Clixby, and only reappears for a few miles between Barnetby and Worlaby.

Ironstone is worked in the middle division, or Tealby Beds, of the Neocomian Series.

The large Alluvial area along the borders of the Trent and Ouse is of considerable agricultural importance, owing to the extensive system of "warping" which is carried on. To this, indeed, the traditional fertility of the Isle of Axholme is partly due.

ARCH. GEIKIE,
Director General.

Geological Survey Office,
Jermyn Street,
February 19th, 1890.

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THE GEOLOGY OF

PARTS OF

NORTH LINCOLNSHIRE

AND

SOUTH YORKSHIRE.

CHAPTER I.

INTRODUCTION.

THE district described in this Memoir belongs entirely to the basin of the Humber, of which river the whole course, except the mouth, is included in Sheet 86 of the Geological Survey Map.

Owing to the dominant north and south strike of the rocks throughout Lincolnshire, a series of parallel ridges and valleys, also trending north and south, forms one of the most marked features in the physical geography of the district. In each of these valleys we find a river flowing northward, or southward, to join the Humber. But while the courses of the minor rivers conform strictly to the line of easiest erosion, the Humber itself cuts abruptly through the successive escarpments and flows from west to east till it reaches the sea.

Though generally spoken of as a river, the Humber is more strictly an estuary, for the tide flows freely along its whole length of 37 miles, its fish are marine, and salt-marshes border its whole course. Of the larger tributaries the Ouse enters the Map near the north-west corner; it receives the Aire, and, after a circuitous course of about 15 miles, flows into the Humber. The Ouse and its tributaries drain a great part of Yorkshire. On the south-west the Trent enters the area at Misterton, flows northward for about 20 miles, and joins the Humber opposite the mouth of the Ouse. The Trent drains a great part of the Midland counties.

The other rivers, though of local importance, are much smaller. Commencing on the north of the Humber, there is the Hull, which joins the Humber at Hull (more correctly Kingston-upon-Hull); this stream drains the low-lands of Holderness and part of the Yorkshire Wolds. The other streams north of the Humber are of little importance, only draining small areas.

South of the Humber an intricate series of streams drained the flat lands in the western portion of the Map, but these are now almost entirely superseded by straight drains or canals flowing into the Trent or Ouse. Among them, however, the Old Don, Idle, and Torne Rivers are interesting as forming the boundary

between Yorkshire and Lincolnshire. Near the centre of the Map is a broad north and south valley drained by the River Ancholme, and its tributaries. The Ancholme has been straitened and turned into a navigable canal called the New River, which flows past Brigg and enters the Humber at Ferriby. East of the Lincolnshire Wolds a few minor streams drain the Chalk and low-lands. The principal of these are the Ulceby, Laceby, and Hatcliffe Becks. The Chalk streams are commonly intermittent, some of them failing entirely towards autumn.

The easterly dip of the Secondary rocks makes the harder beds form north and south ridges with steep escarpments facing westwards. Thus we have, along the western margin of the Map, a wide belt of alluvial and peaty land with low undulating tracts of sand. The soft Triassic beds which underlie these superficial deposits appear as low insulated hills in places, as at Epworth and Crowle.

On the east of the Trent the outcrop of the Lower Lias is marked by a range of high land running northward to the Humber, and declining gently eastward from its summit to the foot of the next range or Oolitic escarpment.

The Oolitic escarpment, known as "the Cliff," is formed by the outcrop of the Lincolnshire Limestone at its junction with the Upper Lias Clays. The steep escarpment slope is broken in places in the lower part by "nabs," or ledges, made by thin ironstone beds in the Middle Lias. From its crest the Oolitic escarpment falls gently eastward to the Ancholme Valley, which has been excavated in the softer upper beds of the Lower Oolites and the Middle Oolite (Oxford) Clay.

From Elsham southward the Middle and Upper Oolite (Oxford and Kimeridge) Clays form a low table land—capped by Boulder Clay, intersected by numerous valleys, and separated from the Wolds by a low-lying tract of Blown Sand and other superficial deposits. The Liassic escarpment attains a height of 200 feet at Burton near the mouth of the Trent; the Oolitic escarpment on Sheffield Hill, near Appleby, is nearly 250 feet above the sea level.

East of the Ancholme, the Chalk Wolds present elevations of from 300 to 500 feet. The Wolds form a strip of boldly undulating country about six miles wide, which is cut off on the eastern side by an old, partially buried, sea-cliff. Between this cliff and the coast no solid rock is seen, the rest of the district to the edge of the Map being a low plain of Drift and Alluvium.

The principal towns within this area are Hull, on the north side of the Humber and near the margin of the Map; Grimsby, half in this Sheet and half in Sheet 85, on the south side of the Humber, not far from its mouth; Brigg, in the valley of the Ancholme; and Goole, on the south side of the Ouse. Of smaller towns these are in Yorkshire, Hedon, in Holderness; Hessle, on the Humber above Hull; North Ferriby and South Cave at the foot of the Yorkshire Wolds; Howden, in the north-west corner of the Map. In Lincolnshire there is Epworth, capital of the Isle of Axholme;

Kirton Lindsey on the Oolite escarpment; Caistor (or Castor) at the foot of the Wolds; and Barton-upon-Humber.

The Geological Formations represented in Sheet 86 are the following:—

- **Superficial deposits.**
  - Recent
    - Blown Sand.
    - Shingle.
    - Alluvium and Warp.
    - Peat.
  - Post Glacial
    - Valley Gravel.
    - Low level deposits of the Ancholme Valley (? in part Newer Glacial).
  - Glacial
    - Boulder Clay.
    - Glacial and Interglacial Gravels.
    - Boulder Clay.
- **Cretaceous.**
  - Chalk
    - Upper Chalk? (not seen at the surface).
    - Middle Chalk, with flints.
    - Lower (or Grey) Chalk, without flints.
    - Red Chalk.
  - Neocomian
    - Carstone.
    - Tealby Beds
      - Tealby Limestone.
      - Tealby Clay.
      - Claxby Ironstone.
    - Spilsby Sandstone.
- Upper Oolite
  - Kimeridge Clay.
- Middle Oolite
  - Oxford Clay.
  - Kellaways Rock.
  - Clay beneath Kellaways Rock.
- **Lower Oolites.**
  - Great Oolite Series
    - Cornbrash.
    - Great Oolite Clay.
    - Great Oolite Limestone.
    - Upper Estuarine Series.
  - Inferior Oolite Series
    - Lincolnshire Limestone
      - Hibaldstow Beds.
      - Kirton Beds.
    - Basement Beds
      - Hydraulic Limestone.
      - Lower Estuarine Series.
      - Dogger.
- **Lias.**
  - Upper Lias
    - Clay and Shale.
  - Middle Lias
    - Marlstone Rock Bed (Rhynchonella Bed).
    - Clay.
    - Pecten-Bed Ironstone.
  - Lower Lias
    - Clays.
    - Frodingham Ironstone.
    - Clays and Limestones (including the Basement Beds).
- Rhætic or Penarth Beds, Black Shales, &c.
- **Trias.**
  - Keuper
    - Marls with Gypsum.
    - Sandstones (Waterstones).

In describing the above formations and sub-divisions it has been found necessary to insert several chapters explanatory of the nature of the junctions or boundaries between divisions, as these have been, in several cases in this area, taken from local peculiarities which have not in every case their counterparts elsewhere, in the areas to the north and south. The Chapters in question are:—The junction between the Lower and Middle Lias (Chap. V.); the junction between the Lower and Middle Oolites (Chap. X.); the relations of the Middle and Upper Oolites (Chap. XII.).

This arrangement has been adopted in order to explain the difficulties, either purely stratigraphical, or palæontological, which were encountered in a district wherein we might expect to find the commencement of that change in character which distinguishes the Oolites of Yorkshire from the rocks of the same age in the Midland Counties.

Palæontologically, the area embraced in Sheet 86 is somewhat exceptional. We find forms, elsewhere regarded as zonal, here exhibiting a wide range, as, for instance, *Ammonites capricornus*, which occurs up to within a few feet below the Marlstone Rock Bed. Again, we have felt justified, from the occurrence of a certain form on the same stratigraphical horizon (though individually not restricted to it), in admitting local zones, such as that of *Ammonites Henleyi* in the Pecten-bed ironstone, taken as the base of the Middle Lias in this area, for reasons hereafter given.

The absence of characteristic fossils, or rather our failure to discover them, such as *Ammonites margaritatus* in the Middle Lias Clay, although that fossil is comparatively abundant in the neighbourhood of Lincoln (Sheet 83), is another difficulty experienced.

To obtain a boundary between the Upper and Middle Oolites, in the absence of any lithological distinction, we are obliged to attach considerable importance to the occurrence of *Ostrea deltoidea* and *Gryphæa dilatata*, the latter being, as far as we know, always stratigraphically lower than the former, whilst at the same time Kimeridgian forms such as *Ammonites rotundus*, through the downward extension of their range, cannot be relied upon. The relations of the Lower and Middle Oolites in Sheet 86 are not clear; as the Clay above the Cornbrash (Avicula Shales) in Yorkshire is included in the Lower Oolites, whilst clay occupying the same relative position in the Midland Counties is taken as the basement bed of the Middle Oolite. In this area the absence of sections and the entire lack of palæontological data, render the classification of this clay, and even its persistence, very uncertain.

CHAPTER II.

TRIAS.

The Triassic rocks occupy only a very small area at the surface in Sheet 86. On the west of the Trent, at Crowle and Epworth, the Keuper Marls with gypseous bands form islands in the surrounding alluvial deposits, but even on these elevations they are partially concealed by Blown Sand and gravel. At Misterton a hill of Keuper Marl, prolonged from the Triassic area of Sheet 83 on the south, rises from the Alluvium. At North Carr Drain south of Misson Level; at Wroot; and at Lindholme, Waterstones are shown on the Map, but as they are entirely concealed by gravels and Blown Sand their occurrence is rather inferred from the adjacent areas on the south and west than proved by observation. A broken line has been drawn through the alluvial area to the north as a boundary between Keuper Marls and Waterstones; this has been done from the evidence afforded by borings.

On the east of the Trent Alluvium the Keuper Marls are only visible in three places, viz.:—On the west of Blyton, on the north and west of Hardwick Hill, and on the Trent bank between Burton Stather and Cliff End.

KEUPER SANDSTONES (WATERSTONES.)

At Sandtoft near the county boundary north-west of Epworth Dr. Parsons* describes a well-sinking in which a white gritty sandstone, considered by him to be Bunter sandstone, was reached. As, however, Mr. Howell has seen nothing to the north of the Humber in the Vale of York which can be identified as Bunter, the sandstone in question is more probably referable to the Lower Keuper, possibly similar to the grey rock met with in the Railway Station well at Naburn, York, and at other places in that district.

The deep boring at Reedness proved 687 feet of Triassic Sandstones below the Red Marl (*see* p. 7).

In the borings at Goole Waterworks (*see* p. 210), Sandstones were also encountered.

KEUPER MARLS.

East of the Trent.

On the north-west of Blyton, Keuper Marls are exposed in a pit, and by the road on the steep slope of the hill. Keuper Marl was observed in Laughton a few chains west of the Church.

* *Proc. Yorksh. Geol. Soc.* N. S. vol. vii. (Pt. 2.), p. 157, 1879.

By the road east of Ferry Flash, and in a pit on the northern slope of Hardwick Hill, Keuper Marls are visible.

By the Trent between Burton Stather and Cliff End weathered Keuper Marls, apparently *in situ*, were noticed in three places, though much obscured by Liassic *débris*; the most northerly exposure is about a quarter of a mile from Cliff End, just above the river, and the most southerly is about half a mile from Burton Stather, at about 50 feet above the river.

West of the Trent.

The following notes on the Triassic rocks on the west of the Trent are by Mr. Cameron:—

The weathered Keuper Marls form a stiff red clay soil over the elevated parts of the Isle of Axholme, and yield good crops. Blown Sand, chiefly drifted from the low-lying land on the western side of the hill, where it is piled in dunes and is still drifting, partially conceals the Marls on the higher lands. On the highest parts the Marl is in one or two places capped by gravel. The term "Isle of Axholme" is not restricted to the three separate hills of Keuper Marls which rise above the extensive flats of Warp and Peat which surround them, but is applied to that part of north-west Lincolnshire which lies to the west of the Trent and is enclosed by that river and the Torne, the Idle, and the Don. Keuper Marls under about a foot of soil form the elevated ground at Ouston.

The higher parts of the hamlets of Park and Upperthorpe are built on Keuper Marls surrounded by Blown Sands: Marls and green shaly beds are exposed in the road between these villages. At Starr Carr and Skiers Flash, Red Marl is visible in the drain-bottoms, under about 4 feet of Peat, the latter apparently thinning out in proximity to the higher ground.

Gypsum occurs at the surface at Epworth and Burnham, and other places on the Isle of Axholme. Its outcrop is represented by a blue line on the Map. Formerly the owners dug out the masses (so near is it to the surface), and filled up the pits again. In character, the Gypsum is thin and fibrous, or massive and concretionary, being found either in thin veins, ramifying through the Marl, or as huge tabular blocks.

At the Low Burnham Quarry and Brick Yard, the Marl and the Gypsum are mixed up together in spherical masses.

Leland thus quaintly describes the Epworth Gypsum, in the Isle of Axholme.

"The upper part of the Isle hath plentiful quarres of alabaster communely there called plaster, but such stones as I saw of it were of no great thickness and sold for viid the lode; they lay on the ground lyke a smooth table and be bedded one flake under another, and at the bottom of the bedde of them be roughe stones to build withal."

At Misterton thin flaggy sandstones occur in red and green Marls.

On the north of the Humber there is no surface exposure of Triassic rocks within the area occupied by Sheet 86. But several wells and boreholes have been carried down through the superficial deposits into the Keuper Marls and Sandstones. These are given in the Memoir on the Geology of the Country between York and Hull.* The deepest boring is that at Reedness, on the south bank of the Humber, three miles east of Goole; this passes through 69 ft. 8 in. of alluvial and other superficial deposits and then through 959 ft. 4 in. of Triassic rocks; the upper 272 feet of which were mainly Marls; the lower 687 feet mainly Sandstones.

A. C. G. C.

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* Mem. Geol. Survey, 1886. This Memoir describes Sheets 93 S.E., 94 S.W., and so much of 86 as lies north of the Humber. Several of the records of borings &c. there given were collected by Dr. H. Franklin Parsons, and are quoted from his papers (*Proc. Yorkshire Geol. Soc.*, N.S., Vol. vi. (Pt. iv.), p. 214, 1877, and Vol. vii. (Pt. ii.), p. 158, 1879.

CHAPTER III.

RHÆTIC OR PENARTH BEDS.

The Rhætic or Penarth Beds, so well exposed in the Lea cutting near Gainsboro' in Sheet 83, and also the representatives of the *Ammonites planorbis* zone of the Lower Lias, which directly overlie them, are very seldom seen at the surface in Sheet 86. Indications of the presence of the Rhætic Beds and of the Basement Beds of the Lias are very meagre as we proceed from Messingham northward to the Humber; whilst the converse is the case with the Liassic strata, from the zone of *Am. angulatus* upwards to the base of the Oolites; we propose therefore to trace the Rhætic and Lias Basement Beds, from Blyton northward, and to pursue the opposite course with the Oolites.

It will be seen, on comparing the Geological Survey Maps 83 and 86, that the high ground bounding the Sands and Alluvia of the Trent valley, on the east, whilst exhibiting a general north and south trend, receded at intervals eastwards, its position in Sheet 83 at Gainsboro' and thence southwards being a mile and a half further west than at Blyton and at Laughton and Hardwick Hill, in Sheet 86; and the trend of the higher ground between Blyton and Hardwick Hill is from 2 to 3 miles further west than the continuation of the feature from Scotter northward to the Humber. The deflection of feature from Hardwick Hill to Scotter (*i.e.*, from west to east) is irregular, and is so considerable that, were it not for a westerly projection of the high ground between Flixborough and Alkborough, surface evidence of Rhætic Beds could hardly be expected to the north of Scotter.

The high ground between Blyton, Hardwick Hill, Scotterthorpe and Scotter is, for the most part, concealed by Boulder Clay and Sand soils; whilst the Sands which mask the lower grounds, and bound the Trent Alluvium, have so widely encroached upon the steeper slopes that the exposures of Keuper, Rhætic, and Lias Basement Beds are very few and far between.

From Scotter northward to Flixborough, the Rhætic Beds are concealed by Sand and Alluvium, the Basement Beds of the Lias being exposed near Messingham Mill, through the Sands at the base of the slope.

From Flixborough to Burton no evidence of Rhætic or Basement Lias beds is obtainable, and the only places where there are indications of them north of Burton Stather, are near Cliff End, where the high ground slopes sharply down to the river, broken by talus and innumerable slips, amongst the tumbled materials of which some meagre evidence is observable.

The probability of the occurrence of Rhætic Beds in the neighbourhood of Burton Stather was pointed out to me by the

Rev. J. E. Cross, of Appleby, before the Survey of the Lower Liassic strata in Sheet 86, south of the Humber, was commenced.

The only evidences of the Rhætic Beds in Sheet 86, south of the Humber, obtained during the Survey of the district are given in the following detailed notes:—

The ditch by the road from Blyton Station to Blyton exposes the Black Shales of the Rhætic, apparently along their strike; a thin layer of selenite was noticed in them. The details of this exposure are given in the Memoir on Sheet 83 (p. 15), as the major part of the section is in that Sheet.

Black Shales appear to have been turned out in excavating the foundations of Blyton Schoolhouse, but they were not seen *in situ* in the village, or on the Keuper Marls forming the steep slope on the north and north west of it.

Between Blyton and Laughton Rhætic Beds have been shown at the surface, but wash from the Boulder Clay precludes any examination of their characters. Near the stream source, south-east of Hall Farm, near Laughton, a blackish soil suggests the presence of Rhætic Beds, the basement beds of the Lias being evidenced by grey and light brown clay soils with surface fragments of hard blue limestone and of bluish and grey shelly limestone, but here again the surface evidence is rendered unreliable by *débris* from the Boulder Clay.

Boulder Clay forms the steep slope trending from Laughton Wood to Scotterwood; at the foot of the slope by a fence shown on the Map, about midway between Hardwick Warren House and Scotterwood, the sides of a pond in a marshy depression surrounded by sand dunes are composed of Black Shales *in situ*.

The Basement Beds of the Lias are exposed in a pit at the west end of Scotterthorpe, and would be no doubt shown in Scotterwood Lane if the section were not overgrown.

Rhætic Beds are evidenced in the following places between Middlemoor and Scotterthorpe:—On the east of the lane to Middlemoor and south of the houses, in a disused clay pit, partly filled with water, a bed of fine-grained, pale pinkish-grey limestone, from 2 to 3 inches thick, is shown resting upon whitish and yellowish clay, with sandy shale (apparently decomposed Black Shales); the stone band probably represents the "Sun-stone" of the south of England, which it resembles in texture.

A similar nodular bed to the above occurs in places upon the Black Shales of the Newark district. As fragments of stone identical in character with this bed occur here and there in superficial gravels on the margin of the Liassic feature in Sheet 86, we may infer that the thin stone band is tolerably persistent. No fossils were obtained in this pit.

By the path on the Map, just south of the letters *oo* in the word Middlemoor, a ditch affords an exposure of the Rhætic Beds for 7 chains, consisting of dark grey shales with rather thick laminæ, shaly arenaceous bands, and finely arenaceous nodular fragments, and a hard, sub-crystalline, grey, shaly arenaceous limestone, well ripple-marked; about a foot beneath this a similar stone band occurs containing Fish Scales and Spines, &c. The following is a list of the fossils obtained from these beds:—

Estheria minuta, *Alberti*.
Myophoria postera, *Quenstedt*.
Cardium.
Fish scales and teeth allied to Oxygnathus. ?
Saurichthys acuminatus, *Ag*.

Pyrites was seldom noticed except in the form of decomposed nodules. The upper part of the exposure is generally of a pale grey tint.

In the ditch by the road leading northwards from the west end of Scotterthorpe further evidence of the Rhætic Beds was afforded by dark grey clay, a piece of selenite, and fragments of buff arenaceous shale.

The above-mentioned exposures, coupled with feature, render the Rhætic and Lias boundary between Hardwick Warren House and

Scotterthorpe relatively definite; but the boundary between Rhætic and Keuper is by no means so, for the evidences of clay under the drifted Sands afforded by ponds in places, between Middlemoor, Cote House and Scotterwood, are by no means necessary indications of Rhætic Beds.

From Scotterthorpe to Scotter and thence to Messingham no evidence of Rhætic Beds or Lias basement beds was obtainable.

Between Messingham and Messingham Mill a small feature is made at the base of the steeper slope by beds which appear to belong to the base of the Lower Lias; on the west of this feature clays underlie the superficial Sands; near the turning to Yaddlethorpe clay comes nearly to the surface and has been worked for brickmaking; the pits were unfortunately full of water, but I was informed by an old man that they had been sunk for 15 feet in blue clay: there were no means of ascertaining the character of the clay below the surface, but it is strongly suggestive of the Black Shales, perhaps re-deposited at the surface. From this place to Burton Stather no evidence of anything older than the zone of *Am. angulatus* in the Lower Lias is visible, the subjacent beds being concealed by talus, Sand and Alluvium. Some doubtful indications of Black Shales were noticed under the Alluvium, at about a mile and a half south of Burton Stather, The presence of Rhætic Beds on the slope may be inferred from an exposure of Keuper Marls through tumbled Liassic *débris* by the river at half a mile north of Burton Stather.

At about half a mile north of Burton Church a rain channel down the steep slope, by the path to Burton Stather, exposes bluish-grey shaly clay for from 20 to 30 feet in vertical height. As we may infer from the exposures near Scotterthorpe that the Black Shales of this area have to a great extent lost the fine lamination so characteristic of them elsewhere, there is no warrant for excluding these beds from the Rhætic series on lithological grounds. But, if we regard them as Rhætic Beds, the *A. planorbis* zone of the Lower Lias can be only a few feet in thickness; whilst, on the other hand, the clay might be included in the basement beds of the Lower Lias on lithological grounds.

At about 90 yards from the summit of the cliff, 12 chains north from the rain channel, whitish tufa and sandy *débris* are visible; for the remaining distance down to the river nothing is met with *in situ*, the soil is reddish-brown and loamy with occasional fragments of Lias limestone, and close to the river bank pale grey, drab, and brown clay is shown, which may be in part decomposed and tumbled *débris* from the Rhætic Beds.

The exposure of Keuper Marls at about 50 feet above the river at half a mile north of Burton Stather, and the occasional discovery of thin fragments of dark shale and shaly limestones amongst the tumbled *débris* of the cliff, afford some slight clue to the position of the Rhætic Beds.

The absence of sections of the Rhætic and lowermost beds of Lias is amply accounted for by the character of the cliff, which, from about 30 feet from the summit, is simply a series of slips, carrying down *débris* of the *Am. angulatus* beds of the Lower Lias to the river margin; and in the occasional exposures through the rents in the broken ground made by minor slips there is no reliable evidence. As, moreover, the Rhætic Beds may have lost their characteristic appearance of papery shale, and may resemble those exposed near Scotterthorpe, it would scarcely be possible to distinguish their weathered *débris* from Lias clays.

The thin shaly fragments of limestone, presumably belonging to the basement beds of the Lias, and shaly fragments of more or less arenaceous character to the Rhætic Shales, and the exposure of the Keuper Marls, whilst rendering the presence of Rhætic Beds in the cliff a certainty, afford no indication of their thickness.

The Ordnance height on Burton Church is 205 feet; if, therefore, we estimate the height of the cliff at half a mile to the north of it at 190 feet, and allow 60 feet from its base up for the Keuper, and 70 feet from the summit downward for the *Am. angulatus* beds, we shall have 60 feet in vertical height wherein to account for the presence of the Rhætic and basement beds of the Lias; and of this it is probable that the Lias

Basement Beds do not occupy more than 30 to 40 feet, which would leave a thickness of from 20 to 30 feet for the Rhætic Beds. At Cliff End the probable boundaries of the Rhætic Beds are at 7 chains, and at about 1½ chains from the summit, respectively; but, as the distance from the fence on the summit to the base of the cliff is considerably underrated on the Map, the lines cannot be drawn in their true positions.

Through the north-north-east deflection of the cliff from Cliff End the Rhætic Beds cannot remain long on its slope; the formation probably passes under the Alluvium on the south of the road from Trent Ness to Alkborough; its disappearance from the cliff, south of Burton, is even more uncertain.

CHAPTER IV.

LOWER LIAS.

In Sheet 86 the Lower Lias beds occupy a belt of country attaining its greatest breadth of four miles in the south, near Scotter and Northorpe, and extending northward, to Whitton, on the Humber, where the strata are concealed by Alluvium, from which they emerge between North and South Cave, on the northern margin of the Map.

To the south of the Humber the Liassic area forms a marked feature near its western margin, dominating the low land of the Trent Valley; its summit is formed of the intercalated limestones and clays of the zones of *Ammonites angulatus* and *A. Bucklandi*; the ground slopes eastwards to the foot of the Oolitic escarpment.

Although largely concealed by Boulder Clay south of Scotter, and by Blown Sands between Scotter and Burton, which latter also render their junction with the Rhætic Beds very uncertain and seldom permit the lowest beds of the series to be seen, the Lower Lias beds in Sheet 86 are of exceptional interest.

The upper part of the zone of *A. Bucklandi* is characterised by the occurrence of an Ammonite allied to that form, viz., *A. semicostatus*. This Ammonite often occurs in ferruginous nodules or beds of limestone, but nowhere in England is its horizon so distinctly marked as in the district under consideration south of the Humber, where it characterises a zone of ferruginous limestones attaining a thickness of from 20 to 30 feet, and called after the locality in which its economic importance was first discovered, and where it is now most largely worked, "the Frodingham Ironstone."

The occurrence of *A. semicostatus* in considerable numbers throughout this lithological horizon is sufficiently marked to constitute a palæontological division, and to make the term Frodingham Ironstone in this district synonymous with the *A. semicostatus* zone.

From Whitton southward to Scotter this zone, from its fossils and ferruginous nature, can be easily distinguished from the beds above and below; but further south it cannot be traced with certainty, as the limestones appear to die out, giving place to loam and clay toward the southern border of Sheet 86, and in the northern part of Sheet 83 the Liassic strata are for the most part concealed by Boulder Clay. Above the Frodingham Ironstone the Lower Lias consists of Clay; below it the limestones of the *A. Bucklandi* zone are interstratified with clay and shale and pass downward into the loamy clays and rubbly limestones of the zone of *A. angulatus*, which rest on the thin even limestones, the shelly limestones, clays and shales of the zone of *A. planorbis* so very feebly evidenced in this area.

Three sub-divisions of the Lower Lias are shown on the Map :—

Lower Lias	Clays.	*Zone of Am. capricornus* to	
		„ „ *Am. oxynotus.*	
	Frodingham Ironstone	„ „ *Am. semicostatus.*	
	Clays and Limestones	„ „ *Am. Bucklandi.*	
		„ „ *Am. angulatus.*	
	Basement Beds	„ „ *Am. planorbis.*	

The Basement Beds, though not separately mapped, are sufficiently important to justify separate description.

Lias Basement Beds; Zone of Am. planorbis.

The basement beds of the Lower Lias, constituting the zone of *Ammonites planorbis*, are very seldom exposed in Sheet 86 south of the Humber, owing to the presence of Boulder Clay and Sand between Blyton and Scotter and of Blown Sands from Scotter northward. The zone of *Ammonites angulatus* on the other hand, is not only well developed but exposed in many pits, on the slope forming the eastern boundary of the Sand and Alluvium of the Trent Valley. The following exposures have been regarded as evidences of Lias basement beds, as we proceed northward from Blyton :—

Between Blyton and Scotton Common, grey and light brown soil with fragments of hard blue and grey limestone forms the surface near the head of a small stream depression, south-east of Hall Farm, east of Laughton.

Mr. Cressey, well-sinker, Scunthorpe, tells me that a well was sunk at the new farm buildings near Laughton Wood, at about 10 chains south of Scotton Common, in 20 feet of clay. The upper part of this must be Boulder Clay. The lower part may be Lias.

Indications of drab clay and shaly limestone were noticed at the bottom of a Boulder Clay pit on the slope near Scotterwood on the south-west. From Scotterwood to Scotterthorpe, and on the east and south-east of Scotterwood, the slope is formed of Lias basement beds.

At a quarter of a mile east of Scotterwood, shelly limestone is exposed by a pond.

At rather more than a quarter of a mile south of Scotterwood dark grey fossiliferous limestones are exposed under a thin capping of Boulder Clay in a quarry. The following fossils were obtained from this quarry :—

Hinnites.
Lima gigantea, *Sow.*
Ostrea.
Modiola minima, *Sow.*
M. pygmæa, *Simps.*
Cerithium semele? *D'Orb.*
Eucyclus Chapuisii, *T. and P.*
Ammonites (young).

At the west end of Scotterthorpe thin shaly buff-brown, somewhat arenaceous, limestones, containing *Pullastra* (? sp.), and grey shales are exposed in a pit, to a depth of from 3 to 4 feet.

South of Messingham Mill the Basement Beds of the Lias make a small outcrop feature at the foot of the steeper slope, as shown in the accompanying sketch (Fig. 1):—

FIG. 1.

Sketch—Section showing feature made by Lias Basement Beds, South of Messingham Mill.

S.S. Blown sand.
AL. Angulatus Beds.
BL. Basement Beds of the Lower Lias.

An exposure on the feature shows shelly limestones in grey clay. The following is a list of the fossils obtained:—

Arca.
Astarte.
Modiola minima, *Sow.*
Ostrea liassica, *Strickl.*
Pleuromya.
P. crowcombeia, *Moore.*
Ichthyosaurus tooth.

Between a half a mile and a mile and a half north of Messingham Mill there is evidence of clay in places under the Sands.

The cutting of the Barnetby and Doncaster line does not appear to expose anything below the zone of *A. angulatus*, to which horizon also an exposure of clay through the Sand at half a mile south of Flixborough Old Church may belong.

Beds of limestone are visible in the stream bed at about half a mile west of Flixborough Church, but they may belong to the zone of *A. angulatus*. The exposure of shaly clay in the rain channel by the path to Burton Stather, north of Burton, has been mentioned in the notes on Rhætic Beds. If Rhætic, the Basement Lias beds can scarcely exceed 20 feet in thickness.

Amongst the *débris* on the broken ground of the slope towards Cliff End the basement beds of the Lias are evidenced by even shaly limestone fragments and pieces of limestone of a different aspect to that which usually characterises the zone of *A. angulatus*.

From the very slender evidence of the character of the basement beds of the Lias, of which the foregoing is the sum, the observations have been given from south to north and separate from the limestones and clays above them, although no stratigraphical separation has been attempted, as it was found more convenient to trace the other beds below the Frodingham Ironstone from the north southwards, and because all the evidence procurable respecting the basement beds of the Lias derives additional importance from the bearing it has upon the position of the Rhætic Beds.

Zones of Am. angulatus and Am. Bucklandi, below the Frodingham Ironstone.

These beds consist of limestones interstratified with thicker masses of loamy clay and shale. The lower beds are generally of a brownish colour, but apart from colour they are recognisable by the occurrence of *Am. angulatus*, of a large *Lima*, and of peculiar cup-shaped nodules, or, more correctly, fragments re-

sembling the mouth of a funnel, to which my attention was first attracted by Mr. Peacock of Bottesford, in the Gravel Pits of Yaddlethorpe, before the investigation of the beds from which they were derived was begun. No hard-and-fast line can be drawn between the *Am. angulatus* zone and the darker clays and shales with interstratified limestones which overlie them; and as the latter are seldom exposed in section the determination of palæontological horizons could only be attempted in the fine section in the Railway cutting west of Frodingham Station. This cutting does not expose the junction of these beds with the Frodingham Ironstone, and the general absence of a marked feature renders the definition of the base of the Frodingham Ironstone frequently uncertain.

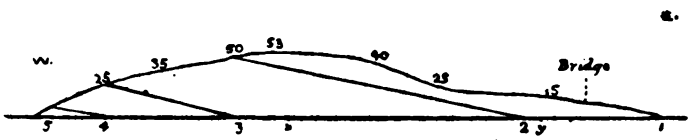
The beds of the *Am. angulatus* zone are exposed on the steep slopes overlooking the Trent Valley in numerous pits; and the whole series, including the Frodingham Ironstone, contains a great abundance of *Gryphæa incurva* (*G. arcuata*). The upper beds of limestone weather to a pale buff, brownish, or yellowish tint, but they can generally be distinguished without much difficulty from the overlying ferruginous limestones.

Prof. Judd* comments on the great thickness of the zone of *A. angulatus* in Mid Lincoln and on its diminution northward. He assigns to the alternating limestones and shales, yielding in the greatest abundance the characteristic fossils of the Zone of *Ammonites Bucklandi*, a thickness of probably not less than 600 feet in the Frodingham cutting of the Manchester Sheffield & Lincolnshire Railway.

By following marked bands from their outcrop by the rails to their outcrop on the top of the cutting, and estimating the height of the latter points, a very fair approximation to the true thickness of the beds may be arrived at. The accompanying diagram represents the cutting on a horizontal scale of about 3 inches to the mile, and a very exaggerated vertical scale of an inch to about 160 feet, which greatly exaggerates the dip of the beds.

FIG. 2.

Section along the Frodingham Railway Cutting.



The upper beds outcropping between points 1 and 2 consist as far as can be seen of irregular grey and yellowish limestones, broken in places, and containing iron shot grains, and numerous Gryphæa &c. These beds

* The Geology of Rutland (Mem. Geol. Survey), pp. 41 and 42; 1875.

appear to be 20 feet or so in thickness, they are probably only a few feet below the Frodingham Ironstone, and are intercalated with drab clay and loam. At point 2 beds of dark grey shaly clay with intercalated limestones crop out and come to the surface over point 3 where the cutting is about 50 feet high.

At *x* the section is as follows :—

Surface soil.	
Yellowish weathered limestones, with *Gryphæa incurva* abundant in hard and brashy beds -	about 10 feet.
Fossiliferous grey limestones in dark grey clay -	about 40 feet.

The bed outcropping at point 3 comes to the surface over point 4, where the cutting is about 25 feet in height. The bed outcropping by the rails at point 4 is at the surface only 5 feet above the rails at point 5 near the termination of the cutting.

The darker grey clay and limestones between points 2 and 3 pass downwards, toward point 5, into drab and lighter grey clays with irregular grey or pale drab limestones which may be taken as the uppermost part of the zone of *A. angulatus*.

At *y* in the cutting there may be a small fault with a downthrow of 2 feet, and at point 4 the beds are either somewhat slipped or intersected by trivial faults having no effect on the succession.

From the western end of the cutting the ground falls in a steep slope, against which the railway embankment abuts; allowing of a thickness of 100 feet for beds belonging to the zone of *A. angulatus* on the slope below the cutting, which is certainly more likely to be an excessive than an under estimate, the thickness of the zones of *A. angulatus* and *A. Bucklandi* below the Frodingham Ironstone exposed in the railway cutting would be certainly not more than 110 feet, which, with the liberal allowance of 100 feet for the beds below, not exposed in section, amounts to 210 feet; I do not think, however, that their total thickness exceeds 170 feet. The railway is wrongly placed on the Ordnance Map, being drawn through Frodingham Church instead of 4 chains to the south of it; and the viaduct is shown about 15 chains north of its true position.

The most northerly exposure of the zones of *A. angulatus* and *A. Bucklandi* in the district is in a quarry opposite Whitton pier, where the following section is shown under from 2 to 8 feet of gravel :—

	Ft.	In.
Brownish clay with a bed of limestone - -	4	0
Dark grey shaly clay - - - about	6	0
Limestone - - - - -		
Brown clay or shale - - - -	8	0
Beds of limestone, more or less weathered towards the base of the section - - -		

The limestones are rubbly, earthy, and in places ferruginous; they contain numerous specimens of *Gryphæa incurva* and *Pentacrinites*.

Mid-way between Bishopthorpe Farm and the north end of Alkborough village, by the sides of a stream, under a soil of alluvial and rainwashed matter, from 2 to 3½ feet of grey clay is exposed. The clay contains numerous Pentacrinite fragments and shells of *Gryphæa incurva* and plaques of limestone. The dip, if any, is very gentle eastwards. This clay cannot be far below the Frodingham Ironstone, which is evidenced at the surface rather more than a quarter of a mile from it in the direction of Bishopthorpe.

At one mile E. 15° N. from Alkborough Church drains have been excavated in clay and limestone. The limestone fragments, dark grey weathering yellow, are fossiliferous, and in places resemble the Frodingham Ironstone beds. Two Ammonites, too imperfect for identification, were found in one fragment.

At one mile east of Alkborough Church a drain showed 5 feet of grey clay weathering brown, and in several places there is evidence of a bed of limestone containing *Gryphæa incurva*, near the surface.

Clay and limestone are visible in a pond 10 chains north of Alkborough.

In a stream bed on the west side of Alkborough, by the road toward Treat Ness, dark grey clay and beds of argillaceous limestone are visible.

At from 57 to 61 chains north of Burton Church, a slip in the uppermost part of the cliff discloses the *débris* of beds of the *A. angulatus* zone and also limestone and clay *in situ* near the surface.

The *débris* consists of brown clay with fragments of grey, earthy, decomposed limestone; and less frequently of hard, bluish-grey, shelly limestone. A small fragment of *Calamite* (or *Equisetum*), *Pentacrinites*, *Lima*, and the peculiar funnel-shaped nodules characteristic of this zone, were obtained. A little rill on the south side of the exposure falls over a cliff 12 to 15 feet high, consisting of tough, grey, rubbly, argillaceous limestone, and dark grey clay or shale. The face of the little cliff is coated with tufaceous matter.

Lower down in talus, 40 to 50 feet from the summit, good specimens of *Lima* and *Cardinia* were noticed; also a bad impression of an Ammonite (? *A. Johnstoni*) and a small piece of *A. angulatus*. The *débris* consists of drab clay with fragments of earthy limestone.

Between Alkborough and Normanby, in the districts uncovered by Sand, the evidence is often so indefinite as to suggest the presence of a thin Boulder Clay soil; the junction of the Frodingham Ironstone with the subjacent beds is very hard to trace, and the latter, owing to their low dip, seem to extend far eastwards in the stream valleys.

In the stream with the long plantation, shown on the Map south-east of Thealby, yellowish clayey matter full of fossils (chiefly *Gryphæa incurva*), under red loam, is suggestive of the presence of beds beneath the Ironstone.

Between Coleby Wood and Normanby the ponds appear to be held up by the clay beds in the *A. Bucklandi* zone.

East of Burton, south of Derby, a farmer told me that the adjacent fields had been deep drained by his father, and that in a depth of 6 feet from the surface (consisting of loamy clay) stiff clay and brashy rock were met with, the beds of rock usually improving as the depth increased.

By the road, a quarter of a mile south of Burton Church, on the slope, the drab clays and limestones of the zone of *A. angulatus* are imperfectly exposed; from this point to Flixborough clays and limestones are exposed here and there in the drains where the surface is not covered by Sand. At rather more than a quarter of a mile north by east of Flixborough Church a pond now marks what appears to have been a quarry of limestones intercalated with clay.

Between Flixborough and Flixborough Old Church grey clays and limestones are imperfectly exposed in a pit on the slope, and in a small pit on the summit beds of grey rubbly limestone were shown to a depth of 4 feet.

Normanby Park is covered with Sand, but this is thin enough in places to afford evidence of the subjacent rock. The Park is on Frodingham Ironstone, for the most part, but the subjacent beds crop out in the plantations by the road to Normanby, and they appear to form a considerable inlier by the streams in the centre of the Park. Signs of clay and limestone are visible by the large pond at the stream confluence south-east of the Hall and in the drains, the sandy soil being very marshy. If not an inlier, this tract will join the main area along the stream at about 14 chains south of the Hall.

In a field on the east side of the road from Scunthorpe to Burton, east of the triangular wood, south of Coneysby Bottom, clay was exposed in cleaning out drains, under 5 feet of Sand; it appears to belong to the uppermost bed under the Frodingham Ironstone. Lias clays, and sometimes limestones, are visible in ponds, pits, and drains both north and south of Coneysby Park House. At about half way between the turnings to Coneysby Park House and to Crosby clay seems to cross the road, its junction with the Ironstone is very indefinite, and as the Ironstone is visible in a well between the turn to Crosby and the bend in the road, the dip is probably in an easterly direction at an angle of 2°.

West of Crosby the junction of the Frodingham Ironstone is very uncertain, whilst the main junction would appear to be in the westernmost part of the hamlet. From the roadside drain, at from 10 to 15 chains further west, numerous fragments of *A. semicostatus* were obtained, and a rock was encountered which might be regarded as the lower bed of the Ironstone; either, therefore, there is but one junction, and that at about 15 chains west of Crosby, or a north and south fault has thrown down the patch of Ironstone west of Crosby. Further west bluish clay and limestone is evidenced. Limestone with numerous specimens of *Gryphæa* occurs at the surface on Frodingham Field; and clay and limestone are partially exposed in pits on the slope between the Railway at Brumby Wood and the road to Crosby. Between Brumby Wood and Yaddlethorpe the beds of the *A. angulatus* zone are exposed in six pits on the slope.

The best section is afforded by a large pit on the north side of the road from Brumby to Burringham Ferry; between it and Brumby Wood partial exposures of the same beds are visible in two large quarries, both of which are concealed in their lower parts by grass and talus.

The pit on the north side of the road from Brumby to Burringham Ferry affords the following section, given in descending order:—

	Ft.	In.
Brown clay soil with blocks of limestone, passing downward into drab and greyish clay with nodular blocks of limestone	2	0
1. Greyish brown clay	1	0
2. Hard, compact, blue limestone - 4 in. to	0	6
3. Drab and greyish-brown clay; bluish in the lower parts, with nodular pieces, or impersistent nodular beds, of impure limestone	6	0
4. Hard grey limestone	0	6
5. Drab clay	1	2
6. Impure nodular limestone, apparently impersistent	0	3
7. Drab and grey clay with nodular fragments, or impersistent beds of earthy limestone, large *Lima*	4	6
8. Very hard even blue limestone (? impersistent)	0	4
9. Grey and brown clay	1	0
10. Decomposed limestone, in part very hard and subcrystalline, with clay partings	0	6
11. Hard grey limestone, with *Lima*	0	6
12. Blue clay to the base of the quarry shown to a depth of	2	6

In a talus fragment, either from the uppermost limestone bed or a lower limestone, *A. angulatus* was obtained. At about 27 chains south of the above a quarry in the hill-side exposes drab, grey, and brownish clay, with beds of limestone, to a depth of 8 feet from the surface; the lower part of the quarry is concealed by talus. The limestones are for the most part impure, and break up irregularly through weathering. Large specimens of *Lima* are plentiful; also the funnel-shaped concretions. A harder bed, not exposed in section, exhibits fucoidal surface markings. An Ammonite (? sp.) was found.

The brown and grey clays and limestones of the *A. angulatus* zone are very partially exposed in the other pits on the slope north of Yaddlethorpe; similar partial exposures, at about the same horizon, of dull grey argillaceous limestone in drab clay occur on the slope in pits:—on the south-west of Messingham by the road to East Butterwick; at a quarter of a mile south, at 44 chains south, and in two pits at about a mile and a quarter south, of the Messingham pit.

Near the road to Frodingham, at the cross roads at the west end of Brumby, yellowish-brown shaly limestones are exposed by a pond. West and south-west of Brumby, in the west part of Ashby, and between Ashby and Yaddlethorpe, yellowish limestones with numerous specimens of

Gryphæa incurva are exposed in drains and proved by surface fragments, and also at three-quarters of a mile north of Messingham. Similar limestones and clays are shown between Ashby and Ashby Grange, in ponds and in a quarry a quarter of a mile north-west of Ashby Grange, upon the slopes of the valley between Ashby Grange and Bottesford, and south of Bottesford.

In cleaning out the ditch by the road toward Twigmoor, between 20 and 35 chains north-east of Messingham Church, beds of limestone were exposed in clays. East and south-east of Messingham the outcrop of the beds from under the Frodingham Ironstone is very doubtful. At about three-quarters of a mile from Messingham there are ponds on the north and south sides of the road to Brigg; blue shaly clay was visible in the pond on the south, apparently associated with limestones, but the height of the water level precluded observation; the same difficulty has frequently occurred in mapping these beds and the Frodingham Ironstone.

South-east of Messingham, at half a mile north of Rannelow Farm, the bottom bed exposed in a long pit may be the uppermost part of the series under the Ironstone. Limestone, with numerous specimens of *Gryphæa*, is proved by surface evidence on the west of this pit, and also at half a mile north-west of Rannelow Farm.

All the Lias of which we have indications about Scotton Wood appears to belong to the Frodingham Ironstone and the overlying Clay.

By the road from Scotter to Kirton, at the Farm on the Map, about three-quarters of a mile from Scotter, the farmer tells me that rock has been encountered under 2 or 3 feet of Sand.

Mr. Thos. Smith, of Scotter, tells me that rock has been got out on the slope opposite Scotter Church; yellowish-brown limestones with numerous specimens of *Gryphæa incurva* are evidenced.

On the slope south of the west part of Scotter drab clays with beds of limestone are imperfectly exposed in three pits at 36, 50, and 80 chains, respectively, west from Scotter Church.

Lias clay is at, or near, the surface near the Scotter end of Scotton Common, as drainage operations (1883) by the road to Scotter disclosed Boulder Clay with foreign stones upon dark grey clay, with fragments probably washed from the Boulder Clay above. Pale grey beds, resembling decomposed limestones, containing numerous specimens of *Lima* occur irregularly in the clay.

North of Scotton Field drains show from 1 to 3 feet of reddish and yellowish sandy soil with bits of flint and foreign pebbles upon bosses of limestone with *Gryphæa*, associated with loam and clay.

Gryphæa limestone and clay is also evidenced on the north side of the stream between Scotton and Scotton Common.

On the north, north-west, and west of Northorpe limestones with numerous specimens of *Gryphæa*, associated with bluish-grey clay, are exposed in drains, &c. At about seven furlongs west of Northorpe two small bosses of shaly limestone, with *Gryphæa*, are shown under Boulder Clay in the sides of a pond.

The beds near Northorpe Station and Southorpe probably belong to the *A. semicostatus* zone; the easterly extension of the Boulder Clay towards these places precludes any further observations of the beds below the Frodingham Ironstone in Sheet 86.

The Rev. J. E. Cross* gives the following list of fossils from the Lowest Lias *in the valley of the Trent*:—

Ammonites Johnstoni, *Sow.*
„ angulatus (var. catenatus, *D'Orb.*, var. moreanus, *D'Orb.*).
Nautilus striatus, *Sow.*
Pleurotomaria basilica? *Chap.*
„ sp.
„ psilonoti, *Quenst.*

* *Quart. Journ. Geol. Soc.*, vol. xxxi., p. 122, 1875.

Turitella Deshayesia? *Terq.*
Cardinia crassissima, *Ag.*
,, Listeri, *Sow.*
,, (oval sp.)
Astarte obliqua, *Desh.*
Pleuromya Dunkeri, *Röm.*
Myacites liasinus, *Ziet.*
Homomya, sp.
Pholadomya prima, *Quenst.*
Cardita Heberti? *Terq.*
Modiola nitidula, *Dunk.*
,, sp.
Arca, sp.
Unicardium cardioides, *Phil.*
Avicula decussata, *Goldf.*
Lima gigantea, *Sow.*
,, Hermanni, *Volts.*
,, hettangiensis, *Terq.*
,, (small ribbed sp.)
Pecten valoniensis? doubtful.
,, (small smooth sp.)
Gryphæa, n. sp.
,, incurva, *Sow.* (var.). (G. arcuata, *Lam.*).
Ostrea irregularis, *Goldf.*
,, rugata, *Quenst.*
,, liassica, *Strickl.*
Carpenteria (Terquemia).
Pentacrinus.
Spines of Cidaris.
Montlivaltia Haimei, *Chap.*

From the Gryphæa incurva (arcuata) zone, *Frodingham Railway Cutting.*

Ammonites Bucklandi, *Sow.*
,, semicostatus, *Y. & B.*
,, Conybeari, *Sow.*
Nautilus striatus, *Sow.*
Belemnites acutus, *Mill.*
Pleurotomaria anglica, *Sow.*
Trochus, sp.
Unicardium cardioides, *Sow.*
Cardinia Listeri, *Sow.*
,, concinna, *Sow.*
Pholadomya ambigua, *Sow.*
Modiola, sp.
Avicula inæquivalvis, *Sow.*
Lima gigantea, *Sow.*
,, Hermanni, *Volts.*
,, dupla, *Quenst.*
,, (small single ribbed sp.)
Pecten textorius, *Schl.*
,, (small ribbed sp.)
,, (small smooth sp.)
Pinna.
Gryphæa incurva, *Sow.* (G. arcuata, *Lam.*).
Ostrea arietis, *Quenst.*
Rhynchonella.
Spiriferina Walcotti, *Sow.*
Pentacrinus, 2 sp.
Montlivaltia Haimei, *Chap.*

From the above list it will be seen that *A. semicostatus* either occurs in beds below the Frodingham Ironstone, and that though most plentiful in the Ironstone is therefore not confined to it, or that the uppermost beds in the Frodingham cutting belong to the Frodingham Ironstone if the fossil has been obtained from the uppermost beds.

Frodingham Ironstone.

The Frodingham Ironstone forms a convenient lithological landmark in the Lower Lias, separating Limestone and Clays below from the Clays above it. It is composed of ferruginous, fossiliferous, limestones not intercalated with clay. Palæontologically* it is the upper part of the zone *of A. Bucklandi*, constituted the subzone of *A. geometricus* by Oppel, that Ammonite being apparently identical with *A. semicostatus* (Young and Bird). The true position of the Frodingham Ironstone was established by the Rev. J. E. Cross, and the results of his investigations were given to the Geological Society in a paper on "The Geology of North-West Lincolnshire."† "It is," he says (p. 118), "undoubtedly Lower Lias and low down in the same. The Ammonites it contains are still chiefly the keeled *Arietes*, or those keeled Ammonites which are next above them: *A. Bucklandi* or some cognate species, *A. semicostatus* (commonest of all, but very badly preserved), *A. Conybeari*, *A. Brookii* of Quenstedt's Jura (which seems not to be Sowerby's *A. stellaris*), the species called *A. aureus* by Dumortier, one solitary specimen which is undoubtedly the *A. Boucaultianus* of D'Orbigny, *A. Boblayi* of Buckman, and two large species which may, perhaps, be identified with figures in Quenstedt's Jura, under the names of *A. Scipionianus* and *A. compressaries*."

Mr. Cross refers the position of the bed to "the border line between Quenstedt's *α* and *β*" (*loc. cit.*, p. 119). He gives its thickness at about 27 feet. "It commences below," he says, "with a hard limestone band, in which, and in somewhat similar bands above, most of the fossils lie; these are intercalated with softer bands of a darker brown colour and rubbly texture, intermingled with a brown dust. . . . . Silica is almost wanting in the Scunthorpe stone, and lime is superabundant. . . . . A good iron ore highly charged with silica has turned up close to the city of Lincoln; and this is now mixed with the mass in the proportion of about $\frac{1}{8}$th of the whole. The yield of metal is about 1 ton to 3$\frac{1}{4}$ of ore; say, 27 or 28 per cent."

Mr. Cross speaks of the Frodingham Ironstone as wholly unknown 15 years before the date of his paper, *i.e.*, in 1860.

Messrs. Daglish and Howse, in a paper entitled "Some Remarks on the Beds of Ironstone occurring in Lincolnshire,"‡ place the Frodingham Ironstone at about the middle of the Lower Lias and give its thickness as about 25 feet. They describe the ore as a calcareous hydrated oxide, with occasional beautiful traces of oolitic structure; it occurs in rich and poor bands; the rich contains nearly 40 per cent. of metallic iron, and the poor, shelly and

* Geology of Rutland, by Prof. Judd, p. 42 (Mem. Geol. Sur.).
† *Quart. Journ. Geol. Soc.* vol. xxxi., pp. 115–130, 1875.
‡ *Trans. N. of Engl. Inst. Engineers*, vol. xxiv., p. 23, &c.

calcareous hard bands as little as 12 per cent., the average proportion being 25 per cent.

The analysis* of the rich and poor Ironstone is given as follows:—

Rich.		*Poor.*	
Peroxide of Iron -	42·24	Ferric Oxide - -	18·85
Protoxide of Iron -	4·16	Manganic Oxide -	3·50
Oxide of Manganese -	1·37	Alumina - - -	3·75
Alumina - - -	4·88	Lime - - -	35·39
Lime - - -	15·75	Magnesia - - -	0·90
Magnesia - - -	1·57	Phosphoric Acid -	0·27
Phosphoric Acid -	0·46	Sulphur - - -	0·05
Sulphuric Acid - -	0·02	Carbonic Acid and Water - - -	34·82
Carbonic Acid and Water - -	22·76	Insoluble and siliceous matter - - -	2·80
Insoluble and siliceous matter - - -	5·28		100·33
	98·49		
Metallic Iron = 32·93 per cent.		Metallic Iron = 13·20 per cent.	

The first furnace at Frodingham was erected by Messrs. Dawes in 1864.

Messrs. Daglish and Howse also allude to the boring for Ironstone west of Kirton Lindsey as follows: "Further south, at Kirton Lindsey, where the Ironstone has been proved at a depth of 50 yards (150 feet), it is said to be too calcareous to be profitably worked."

Mr. Cross's paper affords the best list of fossils in the Frodingham (or Scunthorpe) Ironstone; to it may be appended a large worn tooth of *Ichthyosaurus communis* and large pieces of wood mentioned by Messrs. Daglish and Howse in their paper (p. 25) as having been found in the Ironstone. The fossils obtained from the Frodingham quarries by Mr. J. Rhodes, the Survey fossil-collector, not mentioned in Mr. Cross's list, are also added and are distinguished by being given in italics.

Mr. Cross's list thus supplemented is as follows:—

Ammonites Bucklandi? *Sow.*
" Conybeari, *Sow.*
" semicostatus, *Y. & B.*
" Brookii, *Quenst.* (non *Sow.*)
" aureus, *Dumortier.*
" gmundensis, *Dumortier.*
" boucaultianus, *D'Orb.* 1 sp.

* For further analyses *see* paper by J. D. Kendall on the Iron Ores of the English Secondary Rocks. *Trans. N. of Eng. Inst. Engineers*, vol. xxxv., Part ii., pp. 111–118, 1886.

Ammonites scipionianus ?, *D'Orb.*
„ compressaries ?, *Quenst.*
Nautilus striatus, *Sow.*
Belemnites acutus, *Mill.*
Pleurotomaria Anglica, *Sow.*
Tancredia ferrea, n. sp.
Cardinia gigantea, *Quenst.*
„ copides ? *Rychh.*
„ crassissima ? *Sow.*
Listeri, Sow (*var ovalis*).
„ Morrisii ; ? *Terq.*
„ n. sp.
Astarte dentilabrum, *Ether.*
Cucullæa ovum, *Quenst.*
Pholadomya ambigua, *Sow.*
Plicatula spinosa, Sow.
Myoconcha Oxynoti, *Quenst.*
Modiola Oxynoti, *Quenst.*
„ Morrisii, *Oppel.*
„ scalprum, *Sow.*
Hippopodium ferri, n. sp.
Gervillia betacalcis, *Quenst.*
Lima gigantea, *Sow.*
„ (small variety).
„ Hermanni, *Voltz.*
„ hettangiensis, *Terq.*
„ dupla, *Quenst.*
Lima pectinoides, Sow.
Pecten æqualis, *Quenst.*
„ *æquivalvis, Sow.*
„ demissus, *Phil.*, large, smooth (*P. demissaries*, Cross).
„ texturatus, *Goldf.*
„ *textorius, Schl.*
Gryphæa incurva, *Sow.* (G. arcuata, *Lam.*).
Carpenteria, sp. (*Terquemia*).
Spiriferina Walcotti, *Sow.*
Crinoid arms.
Extracrinus.
Plumaster ophiuroides, ? Wright.
Serpula.
Ichthyosaurus communis, *Conyb.*
Wood.

The following are detailed notes on the occurrence of the Frodingham Ironstone as we proceed from the Humber southwards :—

From Bishopthorpe south of Whitton to the Frodingham quarries the Ironstone beds are exposed here and there in small quarries and pits ; they make a reddish soil, where uncovered by Sand, about West Halton, Coleby, and Thealby ; their junction with the underlying clays and limestones on the west being scarcely marked by feature, whilst on the

east they form a gentle dip-slope inclining towards the West Halton Drain valley, where their junction with the overlying Clay is concealed by Alluvium. From Normanby and Bagmoors southward the Ironstone is concealed by Sand, beneath which it is exposed in quarries, and occurs in places on the surface where the Sand has been drifted away; its junction with the overlying Clay is only visible in one place, at the most easterly extension of the Frodingham quarries.

From Ashby and Manby Common southward to Manton Common the Ironstone exposures are few, and are confined to pits and drains between Ashby Grange and Holme Warren. Near Rannelow the *débris* of the bed has been seen in a roadside ditch; but further south, in the few superficial evidences of the Lias in the Sand and Boulder Clay districts, nothing sufficiently characteristic to warrant the extension of the Ironstone, as a distinct lithological division, is visible.

On the west side of the road from West Halton to Whitton, at about a mile from West Halton, the presence of Ironstone at the surface is attested by numerous fragments, amongst which *Am. semicostatus* was found.

North and west of Bishopthorpe the Ironstone is concealed by superficial deposits.

Ironstone is well shown near West Halton, but its boundary with the underlying beds is by no means certain on the west and north-west.

Ironstone is exposed in a disused pit by the road from West Halton to Alkborough, opposite the path to Coleby shown on the Map. The outlying patch to the north and the termination of the Ironstone west of this pit is far from satisfactory, and flinty soils in places suggest the presence of irregular patches of Boulder Clay.

By a path shown on the Map, at half a mile north-west from Coleby Hall, Frodingham Ironstone has been dug out; the rock is exposed for 18 inches from the surface; it is very fossiliferous, being full of *Gryphæa* and *Pecten;* it often exhibits a siliceous appearance with brown ferruginous interstitial matter; beds of this character about 8 inches in thickness have been got out near the path in a small quarry, which was nearly full of water but exposed rock at from 1 to 3 feet from the surface, and may have been from 6 to 8 feet in depth; the surface soil contains broken pieces of flint.

Ironstone has been quarried on the west side of the road between West Halton and Coleby in three places, respectively 40, 30, and 25 chains from Coleby.

The quarry at 30 chains from Coleby presents the following section of beds, given in descending order :—

	Ft.	In.
Soil from 6 inches to 2 or 3 feet.		
Broken ironstone	1	0
Brown matter, decomposed	0	8
Hard grey limestone partly broken up	0	6
Shaly brown loam with impersistent beds of limestone. The loam may have resulted from decomposition of rock	1	0
Thin beds of hard limestone with partings of decomposed rock, shaly loam	0	9
Hard limestone	0	4
Hard limestone	1	0
Brown shaly matter	0	6
Hard limestone to the bottom of the quarry		

The total exposure of rock is about 6½ feet. The limestones are grey and very hard; they are often compact and rather siliceous. An easterly dip of 1½° was obtained, but in the west part of the quarry the beds appear to be horizontal.

The quarry 25 chains from Coleby presents the best section, the total depth being about 8 feet; the beds exposed are as follows, in descending order :—

		Ft.	In.
	Brown loamy soil with pieces of rock - from	1 ft. to	1 6
1.	Brown broken ferruginous limestone -	6 in. ,,	1 0
2.	Brown loamy shale (decomposed rock) -	6 in. ,,	0 8
3.	Hard brown ferruginous shelly limestone, in places shaly and false-bedded - - - about		1 0
4.	Greyish brown shale (decomposed rock) - -		0 2
	Impersistent bed of hard sub-crystalline grey limestone - - - from	0 to	0 4
	Brown and grey decomposed shaly rock with fossils, passing in places into very hard impersistent limestones - - -	1 ft. to	1 6
5.	Very hard fossiliferous grey limestones, with brown ferruginous matter disseminated in beds—about a foot, from 4 to 6 inches, and 5 inches thick, respectively - -	1 ft. 9 ins. to	1 11

The three bottom beds would furnish good compact stone, but the decomposed matter in beds 2 and 4 appear to be richest in iron.

The following is a list of the fossils obtained from these quarries:—

Gryphæa
,, incurva, *Sow.* (*G. arcuata, Lam.*).
Pecten liasinus, *Nyst.*
Pholadomya.
Unicardium cardioides, *Phil.*
Ammonites semicostatus ?, *Y. & B.*
Belemnites.

Near the path from Coleby in the direction of Coleby Wood, at 9 furlongs from Coleby, brown shelly ferruginous limestones, probably the lowest beds of the Frodingham rock, form the sides of a shallow circular pit.

At about three-quarters of a mile south-east of the above (north-west of Thealby) shaly beds of rather cherty and very fossiliferous Frodingham rock are exposed for a foot or two in a small pit.

Ironstone was noticed in a drain near Coleby, on the south, and in two small pits, near the road between Coleby and Thealby, at 30 and about 55 chains distant from Coleby.

In a quarry by a hedge, between Thealby Lane houses and Thealby, Frodingham rock is exposed to a depth of from 2 to 3 feet; in the upper part of the section it forms a brown decomposed stone-brash resting on tough shelly limestone with numerous *Gryphæa* and small *Pecten*, with a tendency to split in rough irregular flakes. The limits of the outlier of Frodingham rock, shown west of Thealby, are very ill-defined. East of Thealby the Ironstone makes a very red soil.

The Farm, where the stream crosses the road between Thealby and Normanby, is called "Normanby Grange"; near it, on the north, the Frodingham rock is exposed in quarries on either side of the road. The best exposure is furnished by the quarry on the west side of the road, where rock is shown to a depth of 6 feet, under Sand and surface soil from 0 to 3 feet thick. The beds consist of alternations of rubbly fossiliferous limestone and brown shaly matter (decomposed rock), the stone occurs in hard thin beds in places.

Frodingham rock is visible in a small exposure near the path between Coleby and Bagmoor Farm, at about half a mile from the latter, and is proved by surface fragments at 50 chains from Bagmoor Farm in a direction W. 38° N.

There are no sections of Ironstone in Normanby Park, but it was apparently cut into, in excavating the sunk fence near the Hall, and it comes to the surface in a clump of trees, near the avenue, at about 6 chains from the southern gate-house; elsewhere it is concealed by Sand. As the subjacent beds are evidenced in the centre of the Park the thickness of Ironstone in the Park appears to be inconsiderable.

Near the eastern boundary of the plantation, south of the road between Bagmoor Farm and Normanby Park, a quarry exposes about 5 feet of brown, fossiliferous, rubbly limestone, under from 2 to 4 feet of Sand. The exposure may have been 4 or 5 feet deeper, as the lower part of the quarry is filled with water.

Similar rock is evidenced in a disused pit by the road to High Risby, in the plantation about midway between the stream in West Halton Drain valley and Normanby Park.

A pit is shown on the Map, by the road bordering Normanby Park on the south, at 13 chains from the road to Normanby and Scunthorpe; in it, under about a foot of sandy soil in which one or two foreign fragments were noticed, 5 feet of rubbly, broken, fossiliferous limestone is exposed; the beds undulate, but are on the whole horizontal.

At 30 chains, in a direction east-south-east from the above, near a Farm-house at the corner of the plantation, a pit 6 or 8 feet deep, partly filled with water, showed red, rubbly, broken, ferruginous limestone at about 4 feet from the surface.

At rather more than a quarter of a mile from the above, in a direction E. 15° S., a pit, which may have been from 12 to 14 feet deep, filled with water to within 4 feet of the surface, showed similar red-brown, ferruginous, brashy limestone.

Between Coneysby and Normanby Park the boundaries of the Ironstone are very indefinite, especially its lower boundary in Coneysby Bottom.

The upper beds of the Frodingham Ironstone have been quarried in a disused pit (no section) at a quarter of a mile due east of Coneysby.

At half a mile from Coneysby, in a direction E. 30° S., they are partially exposed in a small quarry.

At about 14 chains north of the cross roads at Crosby, red-brown, rubbly, ferruginous rock was observed in a newly made well.

Ironstone has been got out from a shallow pit by a hedge midway between Coneysby Old Park House and Crosby; it appears to be the base of the Frodingham rock.

East of Crosby, near the cross roads, Ironstone is exposed under surface Sand in a quarry.

At a quarter of a mile east of Crosby 6 feet of Ironstone is exposed in a long quarry now worked; there is communication with the main line by a siding.

By the road to Roxby, or Winterton Lane as it is called, at a half a mile from Scunthorpe, Ironstone is exposed in a small quarry. East of this, and 7 furlongs north of Frodingham Station, is the most northerly extension of the Frodingham quarries, which occupy most of the tract between this point and Sandhouse and Gokewell Common on the south. The lower beds of Ironstone are exposed in the quarried tract south of the Railway and on the west side of the road to Scawby and Brigg. In one part of the section, 10 feet of Ironstone is exposed, in another (at the south-east corner of the quarry, between the roads) 5 feet of Ironstone is shown apparently resting upon clay.

North of the Railway, near the southerly termination of the new road by Swaby's Hotel, and at 8 chains from the path between Scunthorpe and the School-house at Frodingham, in a small pit in a turnip field, very ferruginous, red-brown, rubbly rock has been got out under a red-brown sandy soil 2 feet deep.

The thickness of surface Sand on the Ironstone varies considerably in the Frodingham quarries; it increases eastwards, from 2 or 3 to 8 and 10 feet, and near Gokewell Common, to as much as 15 feet. The best exposures of the Ironstone are in the sides of the large quarried tract which extends on the east to the stream near Gokewell Common, and in the quarries leading to the works of Messrs. Cliff. The western face of the large eastern quarry exhibits a thickness of from 10 to 12 feet of the Ironstone; and upon its irregular southern side 15 feet of Ironstone is exposed. Towards the Gokewell stream the upper beds of the Ironstone are to be seen in a narrow extension of the quarry; and at about a quarter of a mile from the Gokewell stream Clay is exposed, under the Sands, and

resting upon the Ironstone. The floor of the large Frodingham quarries is concealed by *débris* of sand, rock, and slag, and by buildings and works. There is no appearance of real faulting in the exposures, but the term "fault" is applied to slight undulations occasionally visible in the beds. The decomposed beds which are the richest in iron do not appear to be persistent, but occur on all horizons, as proved by the extension of the quarries from east to west. The rock varies from red-brown loam to a hard grey and greenish limestone weathering brown; the intermediate variety of brown, or red-brown, irregularly shaly, or broken, ferruginous limestone is encountered at and near the surface, and in the more shallow exposures; but, in places, the stone beds are intercalated with brownish decomposed matter throughout. The harder beds are visible at some feet from the surface. The rock is everywhere very fossiliferous; *Cardinia* and *Gryphæa incurva* being especially numerous, whilst Ammonites are comparatively rare, although in the shallow ditch exposures, near Crosby, and near Rannelow Farm (between Scotter and Manton Warren), fragments of *A. semicostatus* are abundant.

The basement bed of the Ironstone is locally known as "Old Man Rock."

The following information respecting wells in Scunthorpe, of which no written records are kept, was obtained from Mr. Cressey, Well-sinker.

Well at Mr. Tosh's (large new house near the lower outcrop of the Ironstone) between Frodingham Church and the west end of Scunthorpe.

	Ft.	In.	
Sand	3	0	
Ironstone	1	0	
Old Man Rock	1	0	
Blue clay	about 2	0	10 feet sunk in blue clay and limestone under the Ironstone.
Limestone	1	0	
Blue clay and limestone	7	0	

Well at Mr. Swaby's Hotel, Scunthorpe.

Sand, 7 feet Brashy Ironstone Old Man Rock Blue Clay	17 feet sunk.

Opposite Swaby's Hotel, near an old thatched cottage by Mr. Cressey's house, a well was sunk in 9 or 10 feet of Ironstone, under 3 feet of Sand.

In Mr. Skinner's well, between Swaby's Hotel and the Bank, under 6 feet of Sand, a white, mortar-like clay was encountered upon the Ironstone.

At the block of new buildings (shops), on the station side of the Bank, a well was sunk through 6 feet of Sand into the Ironstone to a depth of 8 feet.

Near the Mission House in Winterton Lane about 18 feet of Ironstone was sunk through in the wells, under about 2½ feet of Sand.

In a boring, at about three-quarters of a mile east of Frodingham Station, and nearly half a mile south of the Railway (main line), at a spot now within the walls of the largest Frodingham quarry, Ironstone was sunk into to a depth of 18 feet 5 inches under 1 foot 4 inches of Sand.

In another boring, a mile due east of the above, the whole thickness of the Ironstone was penetrated. The record is as follows:—

	Ft.	In.
Sand	3	0
Blue shale	78	0
Ironstone	30	0
Blue shale	5	0

In a boring at Spring Wood Lodge, about a mile east of the above, and in a boring nearly a mile and three-quarters to the north of it, both begun in the Lincolnshire Limestone (Inferior Oolite), the Ironstone was encountered at 258 and 268 feet from the surface, respectively, and both borings were carried to a depth of 24 feet 3 inches in it.

From the above borings and well-sections a thickness of 30 feet may safely be conceded for the Ironstone, and it would appear to rest upon blue clay or shale (varying from 2 to 5 feet or more in thickness) forming the uppermost stratum of the underlying intercalated clays and limestones.

Between the roads to Scunthorpe and Brumby, east-south-east of Sandhouse Farm, the lower beds of the Ironstone have been got out from shallow surface pits. Both here, and about a quarter of a mile south-west, the Sand drift is either absent or so thin as to allow of the mapping of patches of Frodingham rock by surface indications. On Brumby Warren, south of the Frodingham quarries, the Sand appears to be very thin in places, but it would be a waste of time to draw lines for rock near the surface, and the evidence is not sufficiently conclusive to warrant the certainty of the rock being anywhere actually at the surface.

To the north of the road east of Ashby, in a clay pit at half a mile north of Ashby Grange, the base of the Frodingham rock, consisting of ferruginous rubbly matter, is exposed under Sand, and resting on clay. From this point southward to Holme Warren the lower boundary of the Ironstone is partly recognizable by feature, partly by the vicinity of clay pits at the turning to Ashby Grange and south of Bottesford Beck; the rock was also exposed in the Beck at about three-quarters of a mile up-stream from the place where the Bottesford road crosses it, and, in two shallow pits, about 10 chains apart near the letters *H* and *o* of the words Holme Warren on the Map.

There are two or three ponds south of Holme Hall in the area assigned to the Ironstone, but their sides afford no exposures, and the rock is probably very thin under a Sand surface.

The only traces of Ironstone noticed between Holme Hall and Messingham were obtained at about three-quarters of a mile north-east from Messingham Church, and they are very slight.

Nearly a mile to the east of the south part of Messingham, yellowish-brown shelly rock was observed by a pond; 1 foot of rock was exposed; it appeared to be associated with clay, and contained *Cardinia* and numerous *Pectens*. From its position, this exposure would appear to belong to the Frodingham beds.

Near the above, on the north-east, Lias comes to the surface through the Sand; it is exposed in a pit, and consists of bluish-grey, rather shaly, clay, beneath which stone is said to have been met with; the bottom of the excavation was full of water. A few foreign pebbles were noticed in the surface sand. This clay belongs to the beds above the Frodingham rock, and the latter would appear to crop out from beneath them under the sand surface between this pit and the pond above referred to.

At half a mile north of Rannelow Farm the following section is exposed in a long pit; the beds are given in descending order:—

	Ft.	In.
Sand soil.		
Decomposed rubbly rock, *Ammonites semicostatus* -	0	5
Dark grey shale and loam, possibly decomposed rock from 8 in. to	1	0
Shelly stone bed, containing numerous Pectens -	0	3
Dark grey rubbly clay and shale visible to the bottom of the exposure - - - - about	1	6

It is probable that the upper part of this section belongs to the Frodingham Ironstone series. From the evidence furnished by the ditch by the road to Scotter, near Rannelow Farm, it appears as if the Frodingham beds were associated with clays, the intercalation forming a lithological passage into the Clay series above. The section given above renders an intercalation with clay probable in the lower part of the *A. semicostatus* zone, so that its boundaries are very indefinite in this locality. In the long pit the following fossils were obtained:—

Pecten
P. æquivalvis ?, *Sow.*
Ammonites semicostatus, *Y. & B.*

By the road to Scotter, for some distance west of the turning to Rannelow Farm, after ditch cleaning operations brownish, shelly, broken limestones were exposed, many pieces of *A. semicostatus* and *Cardinia* were obtained. The exposure was very shallow, many of the fossils being obtained from the Ironstone soil. The junction of the Ironstone with the underlying beds appears to run across the hill summit by a pond on the west side of the Farm on the Map, on the south side of the road opposite a turning: from near this Farm, on the east, the ground falls in a dip slope eastward. The junction of the Ironstone with the overlying Clay is, probably either at 3 or at 10 chains east of the turn to Rannelow. Ironstone is indicated on the surface in places and is exposed in drains west and south of Rannelow.

East Carr Farm, a house by a lane leading northwards, is about three-quarters of a mile south of Rannelow. Mr. Pycock, the farmer, told me that rock was found at the surface in a field on the south side of the turning to his farm, and that his well was sunk through the following beds at the farm house:—

		Ft.	In.
1.	Loamy surface soil - - - - about	1	6
2.	Grey sand - - - - - about	1	6
3.	Clay with occasional stones - - -	3	0
4.	Shaly rock - - - - - -	1	0
5.	Dark blue clay - - - - -	1	0
	Hard blue stone - - - - -	0	6
	Shale, depth not tested.		

In this section bed 3 may be Boulder Clay. Mr. Pyrock said that it comes to the surface most irregularly from under the sand. The beds bracketed 5 may be the upper part of the series underlying the Ironstone; bed 4 may be the basement bed of the Ironstone, in which case the rock said to be at the surface near the turning to the Farm would be Ironstone, and its boundary with the underlying beds would be about half a mile west of the turning to East Carr Farm, the ground between being a dip slope. This is the version adopted; if it is incorrect the junction to be substituted for it would be a half mile to the east, and the breadth of the Ironstone outcrop scarcely a quarter of a mile. Near Scotton Wood, on the north and south, Lias is at, or almost at, the surface, shaly brown stone being ploughed up in places and exposed in drains; this rock has been mapped as Ironstone, but the identification is by no means certain.

East of Scotton a broad tract of Alluvium, flanked by Sands, entirely conceals the beds on the horizon of the Frodingham Ironstone. On the northern border of this tract, the ditch forming the eastern boundary of Scotton Pasture shows ferruginous limestone beds under Sand. The limestones resemble the unproductive beds in the Frodingham quarries; the following fossils were obtained from them:—

Cardinia Listeri, *Stutch.*
Gryphæa Maccullochii, *Sow.*
Pecten.

In the stream bank, east of Scotton Wood, a ferruginous bed was noticed under sandy clay; it probably belongs to the uppermost part of the Frodingham rock.

At about a mile from Northorpe Church, in a north-easterly direction, limestone with *Gryphæa* was exposed in the stream bed.

Between Fox Cover and Northorpe, at about three-quarters of a mile north from Northorpe Station, hard rock is shown in a drain, at a foot or so from the surface; it appears to belong to the Frodingham beds. A fragment of *Ammonites semicostatus* was picked up on the surface of the adjacent field.

At half a mile west of Northorpe Hall, in a shallow stream bed, by a hedge, ferruginous, fossiliferous limestone, apparently *in situ*, was noticed. If *in situ*, it is probably interstratified with loam or clay. In a neigh-

bouring ditch a fragment of *A. semicostatus* was found in clay; this cannot be relied on, as, although the Boulder Clay boundary is high up in the Northorpe district, *débris* from it is carried down the slopes.

In this district the Frodingham beds no longer present distinctive lithological characteristics, the lower part of the overlying Clay appears to be sandy, and the beds on the horizon of the Frodingham rock seem to be, for the most part, loamy in the upper part, containing limestones of a more or less ferruginous character, principally in the lower part, as east of Northorpe Station. The underlying beds, on the other hand, seem to be more or less ferruginous, and cannot be separated with any degree of certainty.

North of the road from Northorpe Station to Grayingham a stream ditch affords the best obtainable evidence of the uncertain character of the upper boundary of the *A. semicostatus* zone. Proceeding up stream from the path to the Farm near Northorpe Station, on the Map, we encounter shaly, indurated, finely micaceous, grey and yellowish-brown mottled loam, ferruginous in places. At 8 chains from the path, at half a mile, E. 15° N., from the Station, a tough rubbly ironstone, apparently 3 to 4 feet thick, crops out. This Ironstone bed is overlain by dark bluish-grey clay. Higher up the stream there is an exposure of bluish-grey clay, mottled yellowish-brown, loamy in places, but not indurated as in the first observation. It contains in places impersistent plaques of laminated sandstone, or sandy limestone, and limestone with Pectens. The following is a list of fossils obtained from the sandy ferruginous bed in the stream bank:—

Cardinia Listeri, *Stutch.*
Gryphæa Maccullochii, *Sow.*
Pecten.
Pholadomya ambigua (long var.), *Sow.*
Unicardium cardioides, *Phil.*
Belemnites.

At about a quarter of a mile north-north-west from Northorpe Station, a pit in the plantation, nearly full of water, showed limestones, in part ferruginous and very shelly, in part blue and exhibiting a tendency to split in shaly pieces, resting on grey clay. The limestones contain *Pecten* and *Lima*, a fish jaw (*Hybodus*) was also found.

In the ditch, bounding the plantation near the above (30 chains east of Northorpe Hall), several beds of hard grey shelly limestone, weathering buff-brown, with numerous specimens of *Gryphæa* and of a small *Pecten*, are interstratified with light brown and grey clay.

The following is a list of the fossils obtained from the pit and ditch:—

Cardinia Listeri, *Stutch.*
Cucullæa.
Lima gigantea? *Sow.*
Unicardium cardioides, *Phil.*
Ammonites semicostatus, *Y. & B.*
Hybodus.

Southorpe cottages, surrounded by a large square ditch, are called the Moat Cottages; a drawbridge is said to have spanned the moat formerly. Near the south-east corner of this ditch yellowish-brown ferruginous limestone is shown upon clay. Thick beds of stone, apparently *in situ*, are exposed in one part of the ditch. The inhabitants of the cottages being new-comers could furnish no information respecting their well; they said that the mounds and banks in the adjacent field on the west, called "the Chapel Field," are supposed to be soldiers' graves. A fragment of *A. semicostatus* was found on the surface in this field. It is not improbable that the *A. semicostatus* zone may be represented by the uppermost beds in the moat and by the surface soil in the field, either forming an outlying patch or dipping down the slope to the River Eau.

By the River Eau, near the foot bridge (south border of Sheet 86), under brown and drab loamy soil with pieces of flint and worn foreign stones

from 3 to 4 feet thick, the *A. semicostatus* beds are represented by rubbly, yellowish-brown, decomposed rock in which a fragment of *A. semicostatus* was found, also *Cardinia* and *Pecten*. The thickness of the bed is about 2 feet 6 inches. Blue clay was evidenced beneath it.

The fossils obtained are as follows:—

Cardinia Listeri, *Stutch.*
Lima gigantea, *Sow.*
Pecten æquivalvis, *Sow.*
Ammonites semicostatus, *Y. & B.*

Lower Lias Clay, above the Frodingham Ironstone.

The Frodingham Ironstone is overlain by blue clay and shale, in the upper part of which shaly fragmentary beds or plaques of limestone containing numerous Pectens occur. Owing to its position at the base of the Oolitic escarpment the exposures of the Clay are confined as a rule to pits which have been opened on the margin of the feature usually made by the thin ironstone overlying it. The quantity of Pectens in this overlying Ironstone band induced Mr. Cross to give it the name "Pecten-bed." This bed, for reasons hereafter given, has been taken as the base of the Middle Lias (*see* pp. 36, 37.).

Exposures of the Clay in the low ground from which the Oolitic escarpment rises are very rare; its junction with the Frodingham rock is unmarked by feature, and is generally masked by Sands and Alluvium from the Humber southward to Manton Warren and by Boulder Clay and Alluvium further south.

The Clay was penetrated in borings, at Spring Wood Lodge, south of Appleby Station, and at a point nearly a mile and three quarters further north. In both these borings the thickness of the Clay from top to base was the same, viz., 89 feet 9 inches.

In another boring, west of Spring Wood, begun in the Clay at from 10 to 15 feet below its junction with the Pecten-bed Ironstone, 78 feet was penetrated before encountering the Frodingham Ironstone.

The Clay was also penetrated in a boring near the Railway, 9 furlongs south-west from Kirton Lindsey Station, where the sinking was commenced in the Pecten-bed Ironstone, and according to Messrs. Daglish and Howse "the [Frodingham] Ironstone has been proved at a depth of 50 yards."* If we allow a thickness of 5 feet for the basement Ironstone bed of the Middle Lias and 5 feet for Boulder Clay above it, the thickness of Lower Lias Clay penetrated in this boring would be 140 feet, showing an increase of 50 feet in a distance of 8 miles from north to south.

From Winteringham to Winterton Cliff House the slope below the basement bed of the Middle Lias, which scarcely makes a feature, affords no sections of the Lower Lias Clay, and the Alluvium of West Halton Drain conceals its junction with the underlying Frodingham Ironstone. Frodingham rock is, however, exposed in the middle of the alluvial tract near the road from

* *Trans. N. of England Inst. Eng.*, vol. xxiv., p. 28.

West Halton to Northlands, so that the breadth of outcrop of the Lower Lias Clay in this locality is not more than 15 chains, and as there is no evidence of fault, it must either have an abnormally high angle of dip, about 5° or thereabout, or have attenuated considerably from the thickness of 89 feet, proved in the borings at about four and a half miles further south.

The Rev. J. E. Cross thus describes the Clay above the Frodingham Ironstone*: "A thick bed of blue marl succeeds, 90 feet in depth, its lower portion the home, probably, of *Ammonites oxynotus*; but no opening has been made of any importance in the lower portion of this marl, and its contents are unknown . . . . I have found in it a little *A. Birchii*, Sow. Its upper portion is crossed by bands of chert nodules, and has yielded *Ammonites raricostatus, Taylori*, and, perhaps, the *Polymorphus mixtus* of Quenstedt. A little higher, again, in the same, I find *A. Loscombei, Oxynotus numismalis* (Quenst.), and *Natrix rotundus* (Quenst.) . . . .; with these are a large *Pinna, Pholadomya ambigua* of a huge size, *Gryphæa Maccullochii*, and *Belemnites paxillosus*."

Mr. Cross gives the following list of fossils from the "Clay below Pecten-bed."

Ammonites raricostatus, *Ziet.*
" Taylori, *Sow.*
" polymorphus mixtus? *Quenst.*
" lineatus, *Schloth.*?
" Loscombei, *Sow.*
" oxynotus numismalis, *Quenst.*
" natrix rotundus, *Quenst.*
" Henleyi, *Sow.*
Belemnites paxillosus, *Schl.*
" clavatus, *Schl.*
Myacites unioides, *Röm.*
Pholadomya ambigua (very large).
Sanguinolaria striata, *Buckm.*
Pinna folium, *Y. & B.*
Plicatula spinosa, *Sow.* (small).
Gryphæa Maccullochii, *Sow.*
Spiriferina, sp., very rare.
Terebratula numismalis, *Lam.*
" numismalis ovalis, *Quenst.*
Pentacrinus (very rare).

The mention of *A. Henleyi* in the above list is worthy of note, showing that its range is wider than its apparent prevalence in the overlying Pecten-bed Ironstone would lead one to infer, and confirming its discovery in a large clay pit, 34 to 36 chains south of Gokewell, mentioned further on.

On the slope of Sheffield Hill the Clay is exposed just below its junction with the overlying Ironstone bed in two pits, on the north of the road

* *Quart. Journ. Geol. Soc.*, vol. xxxi., p. 120. 1875.

from Normanby Park to High Risby. Twelve feet of clay is evidenced in the northernmost pit at half a mile from Bagmoor. In the southernmost pit, just north of the road to High Risby, the following fossils were obtained from nodules in the Clay—

Rhynchonella tetrahedra, *Sow.*
Terebratula punctata ? *Sow.*
Cremstula ventricosa, *Sow.*
Gryphæa.
Lima antiquata, ? *Sow.*
Pecten.
Pinna.
Plicatula spinosa, *Sow.*
Hippopodium ponderosum, *Sow.*
,, sp.
Modiola scalprum, *Sow.*
Pholadomya ambigua, *Sow.*
Pleuromya.
Unicardium cardioides, *Phil.*
Belemnites.

The Clay is also exposed in pits occupying similar positions to the above, on the east of Coneysby Bottom, on Lodge Hill, and in four or five pits on Crosby Warren (south of the Ordnance mark and height 226, on Santon Warren).

On the south of the Barnetby and Doncaster Line the Clay is better exposed at its junction with the Pecten Ironstone or just below it.

A solitary example of its junction with the Frodingham Ironstone is afforded by the easternmost extension of the Frodingham and Brumby Warren quarries in the direction of Gokewell Common; here, in December 1882, at about a quarter of a mile west of the stream (Bottesford Beck), the termination of the deeper part of the workings showed about 4 feet of clay, possibly redeposited in the upper, but undisturbed and shaly in the lower, part of the cutting where it rests upon Ironstone: no fossils were obtained from it.

By a disused branch line on Santon Common the Clay is exposed in a pit to a depth of 25 feet below its junction with the Pecten-bed; south of this exposure a road passes under the branch line, and at from 10 to 20 chains south of the Barnetby and Doncaster Line, the junction of the Clay with the Pecten-bed is shown; just below it, a pit is visible in bluish-grey shaly clay, with Pinnæ, &c. At about a quarter of a mile further south, and from thence for about about half a mile, the Clay is imperfectly exposed here and there at its junction with the Pecten-bed in pits. From thence to the little valley in which Gokewell is situated, for nearly half a mile both Clay and Pecten-bed are concealed by Sand and the usual junction feature is absent.

The Clay is shown at or just below its junction with the Pecten-bed, in about 10 pits between the Gokewell stream and the road to Ashby; in about 14 pits between the road to Bottesford and the road to Messingham; and in 9 or 10 pits between the road to Messingham and the M. S. and L. Railway; of these it will only be necessary to allude to those exposures in which fossils have been found in the Clay, many of them being comparatively unfossiliferous and concealed to a great extent by talus, whilst several will be mentioned in the description of the Pecten-bed Ironstone.

At from 32 to 36 chains south of the Gokewell stream a large pit shows bluish-grey shaly clay containing *Pentacrinites*, *Ostrea*, and *Belemnites*, under about a foot of ferruginous rubble (base of Pecten-bed). *Ammonites Henleyi*, Sow., was found on the clay surface, but it might have been washed out of the overlying Ironstone, of which it appears to be characteristic.

At half a mile from Manby in a north-westerly direction, and about 26 chains south of the above, the Clay is exposed in a pit from which the following fossils were obtained:—

Lima gigantea, *Sow.*
Rhynchonella tetrahedra, *Sow.*
Terebratula (Fragments of).

West of Manby the Clay is exposed in a pit below its junction with the Pecten-bed, *Pecten æquivalvis*, and fragments of *Pecten* and *Ostrea* were obtained from it.

In the large clay pit in the south part of Twigmoor farmyard the junction of the Clay with the Pecten-bed is shown; the Clay is exposed to a depth of 8 feet, and furnished the following fossils:—

Hippopodium.
Pinna.
Pleuromya æquistriata ?. *Ag.*
Ostrea.
Ammonites capricornus, *Schl.*

At about a quarter of a mile south of the above the following fossils were obtained from pits in the Clay:—

Avicula inæquivalvis, *Sow.*
Cardium (cast).
Hippopodium (sp.).
Lima pectinoides, *Sow.*
Ostrea.
Pecten æquivalvis, *Sow.*
Ammonites capricornus, *Schl.*
Belemnites.

North of Manton Common, at a mile and a half to the east of Messingham, the upper part of the Clay is exposed in a brick pit; it consists of dark bluish-grey shaly clay with nodules, in which a bad specimen of *Lima antiquata*, Sow., and *Pecten subulatus* (?) were found.

Near the above, on the south side of the road from Messingham to Brigg, at a mile and three-quarters from Messingham, the Clay is exposed in a pit under the rubbly base of the Pecten-bed. The Clay contains fragmentary limestone in thin lenticular pieces, apparently due to solution of the calcareous matter of shells packed closely together here and there. The following fossils were obtained:—

Rhynchonella.
Gryphæa.
Hippodium ponderosum, *Sow.*
Lima pectinoides, *Sow.*
Modiola scalprum, *Sow.*
Ostrea.
Pecten æquivalvis, *Sow.*
,, liasinus, *Nyst.*
Pleuromya.
Plicatula spinosa, *Sow.*
Ammonites latæcosta, *Sow.*
Serpula (fragment).

The Ammonites were found just beneath the Pecten-bed.

From Holme Warren southward to Rannelow Farm and the road to Scotter, the junction of the Clay with Frodingham Ironstone is unmarked by feature and concealed by Sand. In the road to Scotter the junction is slightly supported by evidence, but from thence to the south margin of Sheet 86 the indefinite character of the beds exposed and the presence of sand soils, Boulder Clay, and Alluvium render it very obscure.

By a path at a farm (not marked on the Map), rather over a mile east of Messingham and a quarter of a mile north of the road from Messingham to Brigg, somewhat shaly bluish-grey clay is exposed in a pit; stone is said to have been encountered beneath it, possibly the upper bed of the Frodingham rock.

Near the road to Scotter, at about a mile west of Mount Pleasant, a well has been sunk; the material thrown out from it and banked near it consisted of dark bluish-grey clay with iron and cement stone nodules; one of these proved to be a fragment of *Ammonites armatus*; *Belemnites Pinna*, &c., were also found. Assuming that the Ammonite was obtained *in situ* near the surface, and not washed down the slope, its position would be about 15 to 20 feet below the base of the Pecten-bed Ironstone.

Clay is shown in a pit at 2 miles east from the middle of Scotton village.

In the Boulder Clay districts between Scotter, Northorpe, Grayingham, and Kirton, sections of Lower Lias Clay are very few and the Boulder Clay boundaries are sometimes uncertain. Bluish shaly clay is exposed in the Railway cuttings between Kirton and Northorpe and the Pecten-bed is also partially exposed.

The shaly beds, probably in part belonging to this division of the Lower Lias, which are exposed in the ditch east-north-east of Northorpe Station have been mentioned under the head of Frodingham Ironstone. There appears to be no hard lithological line between the *A. semicostatus* zone and the beds above in this neighbourhood.

The only good section of the Clay in the southern part of Sheet 86 is furnished by a large (now disused) brick pit, nearly a mile from Northorpe Station in a direction east-north-east. In this pit, under a Boulder Clay soil, grey shaly clay containing cement stone nodules, often coated with ferruginous matter, and lenticular pieces of shelly limestone, is exposed. The following fossils were obtained from the nodules :—

Spiriferina Walcotti, *Sow.*
Terebratula punctata, *Sow.*
Lima antiquata, *Sow.*
Pinna.

The top of the section is very little below the horizon of the Pecten-bed.

On the north of the Humber the Lower Lias is only exposed near North and South Cave. It forms the hill to the south of North Cave, where it is seen in the railway cutting, and the beds may be followed round the hill to South Cave where they pass below the alluvial flat and are not again seen north of the Humber.

Between North and South Cave the Lower Lias is covered with great quantities of gravel, composed almost entirely of Lias fragments, in which specimens of *Gryphæa incurva* are especially abundant, showing to how great an extent the Lias must have been exposed to denudation, and also how abundant this particular fossil must have been in those beds.

CHAPTER V.

THE JUNCTION BETWEEN THE LOWER AND MIDDLE LIAS.

The Pecten-bed Ironstone is separated from the Upper Lias by a bed of ironstone representing the Marlstone Rock and an underlying series of clays over 60 feet in thickness, which appear to contain *Am. capricornus*, Schl. (sive *maculatus*) throughout. In these clays it is impossible to establish a boundary either lithological or palæontological. They must either be regarded as Lower or as Middle Lias. "We now reach," says Mr. Cross (*loc. cit.*, p. 120), "the border between the Lower and Middle Lias, the latter represented by some 66 feet of blue clay containing, throughout, in the centres of cement nodules the *A. maculatus* (*Capricornus* of Schlotheim) . . . . . The *margaritatus* beds seem to be wholly missing; and we find only 8 or 9 feet in all between the occurrence of *A. maculatus* and *A. communis*."

The detailed investigation of the district has comfirmed these statements; but the extension of our operations beyond the immediate locality described by Mr. Cross has led to the amplification of his fossil lists in places; and more especially in two important particulars, viz., that, whereas *A. Henleyi* has been found by us in comparative abundance in the Pecten-bed, and only in one doubtful instance below it, *A. armatus* has not been found in it by us, but seems to occur some distance below it. Furthermore, we have discovered *A. capricornus* in the beds below the Pecten-bed.

From these facts I think we are justified in inferring that *A. capricornus* cannot in this district be regarded as a zonal Ammonite, forasmuch as it is impossible to say in its range of from 60 to 80 feet to what part the true position of the zone should be assigned.

Again, the discovery of a single specimen of *A. armatus* in the Pecten-bed by Mr. Cross is no proof of that bed being its zonal horizon, whereas, although found also below it, the prevalence in it of *A. Henleyi* is almost sufficient to induce us to regard that Ammonite as zonal as far as this district is concerned.

If the lower limit of the zone of *A. margaritatus* is to be taken as the base of the Middle Lias, as it has not been found in the clays above the Pecten-bed, these would have to be taken as the uppermost part of the Lower Lias and the Middle Lias would be represented by a Rock Bed, the Rhynchonella Bed, only from 5 to 10 feet thick.

The fact that a certain fossil has not been found in a district where it might be expected to occur, as the sections are so few and so poor, cannot of course be taken as a proof of its absence;

but assuming its presence, it would be quite impossible to draw a line in the clays between the Rock Bed above, and Pecten-bed below, for its limits.

As an instance of the extreme reservation with which we must take the occurrence of Ammonites as evidence of stratigraphical horizons, Prof. Judd may be cited.* In the Rock Bed at "Edmondthorpe, Loddington, and Horninghold *Ammonites communis*, Sow., and *A. annulatus*, Sow., occur in considerable numbers." *A. communis* has also been obtained by me in comparative plenty from a nodular bed in the Middle Lias, near Navenby, south of Lincoln.†

Prof. Huxley and Mr. Etheridge, in their Catalogue of Fossils in the Museum of Geology (1865) make *A. Henleyi* Lower Lias, and *A. armatus*, of Lyme Regis, Lower Lias; but *A. armatus* of Bird's Hill, Radstock, they class as Middle Lias (p. 218 of the Catalogue). *A. maculatus* of Hawsker Bottom, Whitby, is put down as Lower Lias, but *A. capricornus* of Charmouth is regarded as Middle Lias. (N.B.—*A. maculatus*, Y. & B. = *A. capricornus*, Schl.)

The boundary between the Middle and Lower Lias has usually been taken by the Geological Survey in the *A. capricornus* zone, or more properly below the Marlstone, or Rock Bed, at the horizon which exhibited sufficient lithological distinction to enable the surveyor to trace a boundary with some approximation to uniformity. As this boundary or lithological change was usually found to be within the limits of the range of *A. capricornus*, it is said to be in the Capricornus zone, though more properly it might be said to be, as a rule, within the limits of the range of that Ammonite, a zone being the occurrence in abundance at a certain horizon of a certain life form which is by no means necessarily restricted to that horizon; it is in this sense we must speak of the zone of *A. communis*. Where the range of a form is as extensive as that of *A. capricornus*, the congregation of individuals in sufficient numbers to distinguish a particular horizon would be more properly the zone of the fossil, and it is not to be supposed that such zones would be other than local; that is, within the limits of range of a fossil, its zone, or the horizon characterised especially by its presence, might, and probably would, be found at a different stage in different places.

Messrs. Tate and Blake‡ object to the Geological Survey practice of drawing a lithological boundary, on the ground that "this might be an argument for mapping local rock beds under local names and the rest as simply Lias, but will scarcely justify calling beds containing the same fossils Middle Lias when they are rocks and Lower Lias when they are clays, as would have to be done."

* Mem. Geol. Survey, Geology of Rutland, p. 65.
† Mem. Geol. Survey Sheet 70, p. 42.
‡ The Yorkshire Lias, 1876, p. 219.

Mr. Barrow does not fully meet this objection by stating that "the base line for the Middle Lias . . . . passing through the middle of the zone of *A. capricornus* . . . . adopted by the Survey for the rest of England . . . is a line that can be accurately traced. It is impossible to map any boundary line between this and the top of the *A. oxynotus* beds . . . . . In addition, the sudden lithological change is accompanied by a very marked change in physical conditions; down to the base of the Middle Lias there is an abundance of Molluscan shells, whilst in the very uppermost portion of the Lower Lias there is a marked paucity of fossils. Hence this line is easy to trace, is warranted by physical reasons, is of practical utility; and, moreover, has been followed continuously throughout England."*

As applied to a small part of the Liassic area of England no doubt the above is sufficiently conclusive. The earlier Memoirs of the Geological Survey seem to show that the boundary taken between Lower and Middle Lias is one based on lithological change, and this change has been taken in many cases as sufficient without any reference to Ammonite zones.†

In Prof. Hull's Memoir‡ there is no mention of *A. capricornus* (sive *maculatus*), but *A. Henleyi* is given as a representative fossil of the top beds of the Lower Lias, as also in another Geological Survey Memoir.§ Dr. Wright,‖ Messrs. Tate and Blake¶ and M. Oppel, 1856, concur in taking the boundary between Middle and Lower Lias at the base of the Zone of *A. Jamesoni*, called by Messrs. Tate and Blake the Region of *A. armatus*. Prof. Judd** says: "At Little Bowden brickyard . . . . we find the micaceous clays of the Capricornus-beds forming the top of the Lower Lias series." But the same author, p. 74, gives a list of fossils from the lowest Middle Lias beds exposed "at the foot of the Hill on which the Neville-Holt ironworks were opened," in which the only Ammonite mentioned is *A. capricornus*." (*Ibid.*, p. 72) Prof. Judd describes the lower beds of Middle Lias in Cranhoe brickyard as "light blue stratified clays with layers of concentric balls of ironstone, which fall to pieces on exposure to the air. These nodules contain numerous but imperfectly preserved fossils, and it is evident that the beds which contain them are near the junction of the Middle and Lower Lias." The list of fossils which follows contains *A. Henleyi*, and strongly resembles the facies characterizing the clay just below the Pecten-bed, which I would unquestionably regard as Lower Lias, though many of the forms are common to the Pecten-bed itself and to the clay overlying it.

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* Mem. Geol. Survey, Explanatory of Quarter-Sheet 95 N.W., p. 11.

† Mem. Geol. Survey, Banbury and Woodstock, on Sheet 45, 1864. *Also* Mem. Geol. Survey, parts Wilts and Gloucester, on Sheet 34, 1858, p. 6.

‡ Mem. Geol. Survey, Geology of the Country around Cheltenham, Sheet 44, 1857.

§ Mem. Geol. Survey, Sheet 45, 1864.

‖ Palæont. Soc. for 1861.

¶ The Yorkshire Lias, p. 16, &c.

** Mem. Geol. Survey, Geology of Rutland, p. 75.

From Prof. Judd's Memoir we cannot base any definite conclusions as to the maximum, minimum, and mean thicknesses of the Middle Lias below the Marlstone in the area he describes, but reference may be made to p. 69, where the succession at the village of Billesdon is given as follows:—

"1. Rock bed.
2. Light blue clay with bands of sandy ironstone (few fossils) about 30 feet.
3. Dark blue clay with Septaria; numerous fossils; 15 feet seen."

Here they do not seem to be disposed of in 45 feet. Compare also, on or near Slawston Hill, (p. 77.)

"3. Marlstone rock-bed, very inconspicuous and scarcely traceable.
4. Clays, with bands of soft yellow and brown sandy ironstone full of small shells, *Cardium truncatum*, Sow., *Pecten æquivalvis*, Phil., &c.
5. Clay, with ironstone balls.
6. Clays imperfectly seen.
7. Hard ferruginous and somewhat calcareous bed, perhaps the lowest of the Middle Lias series."

"The Middle Lias at this spot may be from 60 to 70 feet in thickness."

From Prof. Judd's Memoir, which is the most complete Geological Survey description of the Liassic rocks, there is no precedent against our drawing the line between Middle and Lower Lias at the base of the Pecten-bed. Bed 7 in the Slawston section, above given, and the Cranhoe brickyard fossils would favour this; on the other hand, the apparently higher range of *A. capricornus* in North Lincolnshire might suggest a very hypothetical boundary in the clay a few feet below the Rock bed, or it might warrant our regarding the Pecten-bed as the uppermost stratum of the Lower Lias.

To turn to Yorkshire. In the Scarboro' and Whitby area we find* that the Middle Lias "is divisible into two parts; the upper consisting of shales with thin bands of ironstone of variable thickness, the lower of sandstones and hard shales, with sandy thick beds of *Gryphæa*, *Cardium*, &c., constituting a sandy marl."

"The beds of the Lower or Sandy Series are remarkable for prodigious numbers of fossils . . . . . Of these *Cardium truncatum* is the chief . . . . . In the lower part *Gryphæa cymbium* predominates and is accompanied by *Avicula inæquivalvis*; calcareous bands near the base often consisting entirely of these two species . . . . . *Belemnites* and *Pecten* are tolerably abundant throughout."

In the section of these beds given, 54 feet 4 inches in all, *A. margaritatus* is noticed in a bed at about 13 feet from the

* Mem. Geol. Survey, Explanatory of Quarter-Sheet 95 N.W., pp. 9, 10.

top, and *A. capricornus* is mentioned, up to about 18 feet from the top. Allowing an average of about 90 feet for the upper, and 70 feet for the lower divisions of the Middle Lias in this area, in which they are well developed, there is, unfortunately, no parallel to be drawn between them and the North Lincolnshire beds, as the Whitby and Scarboro' Middle Lias decreases very much in thickness traced towards the Humber.

The only specimen of *Gryphæa cymbium* obtained in Sheet 86, south of the Humber, was from the Pecten-bed near Twigmoor. The absence of *A. margaritatus*, or rather, our failure to discover it, and the fact that the clays below the Rock bed are not arenaceous, render the Whitby and North Lincolnshire types still further removed.

Cardium truncatum has been found in the lower part of the clay above the Pecten-bed near Harpswell in Sheet 83, but it has not been identified amongst the fossils obtained from the Pecten-bed, nor from the clays above and below it, in Sheet 86, south of the Humber.

If the discovery of *A. armatus* by Mr. Cross in the Pecten-bed is sufficient to prove that bed to be its zone, we would, judging by the Yorkshire evidence, have to regard the Pecten-bed as Lower Lias, and either to take all the clays between it and the Rock Bed as Middle Lias, or to draw a line through them (the clays), unwarranted either by palæontological or lithological considerations. Upon the whole, we are strongly inclined to regard the Pecten-bed as the base of the Middle Lias, taking the discovery of *A. armatus* in it as proof of the locally high range of that Ammonite above the normal position of its zone. When we take into account the extreme probability of the local predominance of life forms at various horizons within the elastic limits of their ranges, and also the many physical changes interfering with or interrupting the continuity of deposits of a certain character in far removed and even in contiguous areas, there is no ground for dispute respecting so indefinite a boundary as the junction between the Lower and Middle Lias. There must be a liberal allowance for discrepancy, both palæontological and stratigraphical, in tracing any boundary line, and the only safe rule to follow is the adoption of lines which combine lithological distinction with palæontological change; where this cannot be done, and it is impossible, from concealment by Drift or other causes, to trace a boundary by relative position, the next area on the line of strike must be treated chiefly on its own merits, avoiding as much as possible any appearance of discrepancy with districts on either side of it in which the sequence though not analogous, is sufficiently manifest. The above reasoning is applicable to the relations of Lower and Middle Lias in Sheet 86. Their relations are concealed by Drift in the adjacent Sheet to the south, which does not permit observation of the behaviour and change of the beds, and on the north the North Lincolnshire type is cut off by the Humber from the Yorkshire area, the south part of which is more obscure than the North Lincolnshire area itself.

As the junction of the Pecten-bed with the underlying clay is most easy to trace, as *A. capricornus* occurs in the Clays below as well as above it, and for the convenient purposes of classification and description, we have adopted a tripartite division of the Middle Lias in North Lincolnshire, thus :—

Rock Bed.
Clay, with lines of nodules and septaria.
Pecten-bed ironstone.

CHAPTER VI.

MIDDLE LIAS.

Pecten-bed Ironstone.

Separated from the Frodingham Ironstone by about 90 feet of Lower Lias clay and shale, is a thin stratum of ferruginous limestone, to which Mr. Cross, in the paper before cited, thus refers (p. 120): "A narrow ironstone-bed . . . consisting of a rocky band 4 feet thick, the slabs crowded with Pectens of a good size. They resemble the shell which Phillips figures, in his 'Geology of Yorkshire, under the name of '*sublævis*,' Young and Bird; (on turning to 'Young and Bird,' however, I think that for *sublævis* we should read '*subrufus*.') From this profusion of Pectens we have named the bed the *Pecten*-ironstone. The Ammonites it contains are *A. armatus* and *Henleyi* . . . I must mention one other of its fossils, a large *Tancredia*, which seems wholly new, and to which I would give the name '*liassica*.'"

Mr. Cross gives the following list of fossils from the Pecten-bed:—

Ammonites armatus, *Sow.*
„ Henleyi, *Sow.*
Belemnites elongatus, *Mill.*
Rhynchonella variabilis, *Schl.*
Terebratula punctata, *Sow.*
Spiriferina (very rare).
Cardium multicostatum, *Phil.*
Cardinia hybrida, *Sow.*
Cucullæa, sp.
Cypricardia, sp.
Cyprina, sp.
Goniomya (rare).
Lima antiquata, *Sow.*
„ Hermanni, *Voltz.*
Myacites unioides, *Röm.*
Nucula.
Pecten corneus, *Goldf.*
Pecten, sp. (like sublævis, *Phil.*).
Tancredia liassica, n. sp.
Unicardium cardioides, *Phil.*

Where unweathered this bed seems to consist of a very hard massive rock, to judge from blocks got out from the Boreholes near Low Santon Farm (west of Appleby Station) and near Kirton Lindsey. The thickness of the Pecten-bed, as given in borings at Spring Wood Lodge, and three-quarters of a mile

further north (between Santon Warren and Appleby Station), is 4 feet 2 inches; and, judging from its surface exposures in Sheet 86, south of the Humber, its thickness would appear to be uniform, or very nearly so.

Owing to its position, near the base of the Oolitic escarpment, separating thick strata of clay, where not exposed in section, the presence of the Pecten-bed is very frequently indicated by a feature, breaking the slope in a minor escarpment with dip slope, or horizontal bed-platform, sometimes very narrow, in places of considerable breadth. This tendency to form subsidiary features frequently gives a greater superficial outcrop to the Pecten-bed than is presented by the overlying series of clays, considerably more than ten times its thickness.

The bed-ledge, or dip-slope, of the Pecten-bed also forms a resting place for sands blown eastward from the warrens at the foot of the Cliff.

In the southern part of the district, where the surface is covered by Boulder Clay, the position and extent of the Pecten-bed is sometimes very doubtful.

Mr. Strangways communicates the following note:—

The Pecten-bed forms a narrow band till just west of Winteringham, where it spreads into a bolder feature, the fields south-west of the Church being covered with fragments of the rock, which have the characteristic fossils in great abundance.

C. F. S.

From Winteringham to Winterton Cliff House the Pecten-bed affords no exposures worth mentioning, and, except in the vicinity of Winteringham Church, it is scarcely marked by subsidiary feature.

Mr. James Green of Coleby informed me that this bed has been dug for ironstone on the slope between Northlands and West Halton, east of the spot where Frodingham Ironstone is exposed in the West Halton Drain flat; no section is now visible.

From the slope below Winterton Cliff House southward to the Barnetby and Doncaster Line, the Pecten-bed is generally well marked by a feature breaking the slope in a narrow ledge, or, in a series of small nabs or mounds; it is also exposed at intervals in pits showing its junction with the Clays beneath.

The best of three exposures of the Pecten-bed between Bagmoors and Winterton Cliff House is furnished by a ditch at half a mile west of Roxby, where it is exposed to a depth of 3 feet, made up as follows:—

	Ft.	In.
Brown, rubbly, ferruginous rock, with numerous casts of Pectens	2	0
A bed of hard ferruginous limestone	1	0

The following is a list of fossils obtained from these beds:—

Rhynchonella tetrahedra, *Sow.*
Gryphæa gigantea, *Sow.*, (Cast of.)
Lima.
Lima antiquata, ? *Sow.*
Pecten æquivalvis, *Sow.*
Cardita.
Cardinia Listeri, *Stutch.*
Cypricardia intermedia, *Moore.*
Tancredia ovata, *Terq. and Piette.*

The Pecten-bed is well shown in two pits on the slope of Sheffield Hill, on the north side of the road from Normanby Park to High Risby. The northernmost pit, half a mile from Bagmoor, gives the following section :—

	Ft.	In.
Surface sand	3	0
Broken ferruginous rubble	1	6
Ironstone with numerous Pectens (broken) in the upper part	2	0
The underlying Clay is shown through the talus on the sides, and at the bottom of the pit, in all to a depth of	12	0

The following fossils were obtained from the Ironstone :—

Pecten æquivalvis, *Sow.*
,, liasinus, *Nyst.*
Cardinia Listeri, *Stutch.*
Cypricardia intermedia, *Moore.*
Tancredia ovata, *Terq. and Piette.*
Belemnites.

The other pit does not afford as good a section of the Pecten-bed ; it is a few chains further south, by the road to High Risby.

Between Sawcliff and Willow Holt the Pecten-bed is affected by a fault, with a downthrow to the south, shifting its outcrop a few chains westward and displacing the accompanying feature. From this point to the Railway the Pecten-bed is marked by a distinct feature, and its base, a ferruginous rubble, is visible in pits exposing the underlying Clay, near Lodge Hill, and the letters *rr* in the words Crosby Warren on the Map. The Barnetby and Doncaster Railway is very much misplaced upon the Ordnance Map. High Santon Farm is nearly half a mile south of the words High Santon on the Map, and at the foot of the Middle Lias Clay slope, below the true position of the Farm, a disused short branch-line terminates. This branch joins the main line at about a mile and a half from Frodingham Station. The Pecten-bed is well exposed in the road-cutting between the branch and main lines ; it is also visible in a shallow cutting by the main line.

By the road, now mended and extended, which is the most direct route from Scunthorpe to Appleby Station ; near the branch line, the junction between the Pecten-bed and underlying Clay is well shown. The ferruginous rubbly base of the Pecten-bed is also visible in several clay pits near the temination of the branch line.

At about 30 chains south of the termination of the branch line the Pecten-bed feature becames almost irrecognisable, and from thence to Gokewell Valley a flattish sandy tract and thick woods obscure all indications of the position of the bed.

From the Gokewell Valley to Low Wood, near Raventhorpe, the Pecten-bed is exposed here and there in pits in the underlying Clay.

At 30 chains south of the Gokewell stream about a foot of ferruginous rubble, the base of the Pecten-bed, in which *A. Henleyi* was obtained, is exposed on top of the Lower Lias Clay in a pit.

At about half a mile north-north-west from Manby the Pecten-bed is exposed in a ditch, in the vicinity of which numerous fragments of the rock have been turned out from drains ; from these fragments the following fossils were obtained :—

Pecten æqualis, *Quenst.*
Modiola scalprum, *Sow.*
Myacites (Pleuromya) unioides, *Röm.*
Pleurotomaria.
Ammonites striatus, *Rein.*

In five or six pits from which Clay has been dug, near the borders of Manby Common, the base of Pecten-bed is exposed, consisting of decom-

posed, rusty-brown, fragmentary ferruginous rock ; but it is so much decomposed and so thin that the fossils obtained from it could not be identified with certainty.

In a pit by Low Wood, about 30 chains south-west from Manby, about a foot of Pecten-bed rubble is exposed on the Clay. *Pholadomya ambigua* Sow. (var.), and *Belemnites clavatus* (?), Blainv., were obtained from it.

Between the roads to Ashby and Bottesford the Pecten-bed is entirely concealed by Sand.

At about 12 chains south of the road to Bottesford the ferruginous rubbly base of the Pecten-bed is exposed in a pit near the north-west corner of Twigmoor Warren. From this pit the junction-feature is maintained for some distance, and along it the base of the Pecten-bed is visible in pits here and there, as far south as Manton Common.

At about 5 chains south of Twigmoor Farm, 1 foot of shaly ferruginous stone is exposed in a large pit in the Clay below the Pecten-bed.

At about 20 chains south-south-west from Twigmoor Farm the Pecten-bed was cut through in a ditch in the vicinity of two pits in the underlying Clay. It consists of shaly ferruginous limestones from which the following fossils were obtained :—

Cypricardia.
Gresslya lunulata *Tate*, (like Myacites).
Gryphæa cymbium, *Lam.*
Modiola scalprum, *Sow.*
Myacites (Pleuromya) unioides, *Röm.*
Pecten æquivalvis, *Sow.*
Pinna fragment.
Pleurotomaria.
Rhynchonella tetrahedra, *Sow.*

The outcrop of the Pecten-bed from beneath the overlying Clay is entirely concealed by the Sands of Twigmoor Warren and the north part of Manton Warren. The land rises westward forming a promontory toward Messingham ; at the termination of this feature the base of the Pecten-bed, consisting of a foot of hard rubbly rock, is shown in a pit, upon Lower Lias Clay containing fragmentary limestone crowded with Pectens.

Between the above and the Twigmoor pits, previously mentioned, there are several clay pits on the slope ; one of these shows the following section :—

	Ft.	In.
Rubbly ferruginous rock - - - about	1	0
Tough brown ironstone - - - - -	1	0
Lower Lias Clay, to base of exposure.		

From one of these pits, two miles from Messingham Church, the following fossils were obtained :—

Rhynchonella tetrahedra, *Sow.*
Cardita (?).
Cypricardia.
,, intermedia, *Moore.*
Myacites (Pleuromya) unioides, *Röm.*
Unicardium globosum, *Moore.*
Pleurotomaria (cast).

East of the above, near a farmhouse by a wood, at a mile and three-quarters south-east from Bottesford Church, a partial exposure by a pond exhibited brown soil with fragments of ferruginous rock, on bluish and dark grey clay with bits of Belemnites ; on the northernmost side of the pond there is an appearance of a fault with a small downthrow to the north, but the position of the ferruginous material which suggests it may be due to a slip.

Owing to the very irregular surface of the Sand, blown into dunes and hillocks, it is very uncertain whether the Pecten-bed forms a continuous

sheet on its dip-slope in the vicinity of the pond last mentioned. A similar difficulty is presented wherever dip-slopes of considerable extent formed by either the Marlstone (Rhynchonella Bed) or Pecten-bed are covered by Sand, as owing to the thinness of either bed, the subjacent Clays might have been exposed in patches through the denudation of the stone bands on their dip-slopes prior to the drift of the Sands.

The junction feature of the Pecten-bed and underlying Clay disappears to the west of Manton Warren House. A pit on the south side of the road to Messingham shows the base of the Pecten-bed, consisting of from 1 to 2 feet of rubbly ferruginous material upon Clay with *Belemnites* and *Pecten*, &c.

At about half a mile north-west of Manton Church the junction feature is again visible; the Pecten-bed is partially exposed as a ferruginous rubble in drains under Sand, the underlying Clay, with fragments of *Pecten*, *Belemnites*, &c., being also exposed.

From the Manton stream southward to the Cleatham stream the junction feature is well marked; Lower Lias Clay is exposed in several pits, the presence of the overlying Pecten-bed being usually determinable by soil and surface fragments.

In the copse, east of the Tumulus, near Cleatham, the Pecten-bed is exposed at about 7 chains up a tributary of the Cleatham stream. The exposure consists of 6 inches of bluish-grey concretionary rock, partly ferruginous, and resting upon blue Clay.

Just above this exposure the stream cascades over a bed-ledge of the rock which occurs in thin irregular beds affording a total visible thickness of about 2 feet.

On the north side of the sandy lane from Manton toward Scotter, at about half a mile east of Rannelow, dark grey Clay, weathering to a lighter hue and containing *Belemnites*, is shown by a pond; certain stony fragments, which might be due to the breaking up of nodules or impersistent shaly beds in the Clay, suggest the possibility of the presence of a small outlier of the Pecten-bed, on the Lower Lias.

From the Cleatham stream southward, the relations of the Pecten-bed are rendered very obscure by the presence of sandy soil and relics of Boulder Clay; as the dip-slopes thus partially concealed between the stream near Cleatham and the Railway are of considerable extent, it is not at all improbable that subsequent drainage operations, might prove the mapping slightly inaccurate in some places.

The presence of Boulder Clay in the neighbourhood suggests a destructive agency which could not fail to affect such rubbly material as the Pecten-bed is composed of, and which might, in cases where the sole evidence for mapping the Pecten-bed at the surface consists of a ferruginous soil, have obliterated all traces of the actual rock.

West of Mount Pleasant, near the Farmhouse on the south side of the road to Scotter, trial workings for ironstone reveal the presence of the Pecten-bed on the lower part of its dip slope, but no sections are now visible.

The Pecten-bed has been shown at the surface west of Kirton Station on the evidence of soil; but, on the low ground to the south of this, and in the valley on the north, the mapping is entirely conjectural; and on the west of Kirton Lindsey the Ordnance Map is defective. By the northernmost of the two roads leading westward from Kirton to the Railway, a scarcely perceptible feature is made, on the low ground, by brown ferruginous stone-brash, very siliceous in part; and, between this road and that on the south, tough siliceous stone is visible in two places, apparently striking north and south. From these indications, if we assume this to be the normal outcrop of the Pecten-bed, as it cannot be traced southward by feature or surface indications, we must either suppose, that it forms a narrow inlier, produced by a gentle undulation in dip, or, that it is continuous, in a sheet or thin band, under the superficial deposits, with the patch on the north and the exposure of the bed in the Railway cutting on the west.

The evidence afforded by the two Railway cuttings between Kirton and Northorpe Stations is as follows :—

At about 76 chains from Kirton Station, the first cutting commences in bluish shaly Middle Lias Clay. From the commencement of the cutting the distance of each observation is measured. At 5½ chains there are indications at the base of the cutting of the outcrop of the Pecten-bed. At 10 chains the Pecten-bed is shown by a path up the west side of the cutting, it consists of yellowish-brown ferruginous rubble on a hard irregular grey and purplish stone-bed, both together about 5 feet in thickness; beneath it dark blue fossiliferous Lower Lias Clay is visible. The Pecten-bed appears to crop out under the Boulder Clay surface at 15 chains, near a Bore Hole. The rest of the cutting, for 20 chains, affords no evidence of the Pecten-bed. The next cutting is about 18 chains further on, it is 25 chains long, and consists of bluish shaly Lower Lias Clay. The partial exposure of the Pecten-bed in the first cutting is due to banking-up and grass growth. At the Bore Hole, on the south side of the cutting, large blocks of hard, brown, fossiliferous ironstone are visible on the floor of some grass-grown surface workings; these blocks resemble those got out from the sinking near Low Santon Farm (west of Appleby Station) which are said to exhibit the Pecten-bed in its natural and unweathered state.

From the Railway cutting southward the relations of the Pecten-bed to the overlying Clay are very indefinite, as Boulder Clay conceals the solid rocks on the higher ground, and Sand soils and Alluvia obscure them in the valleys.

In the valley, three-quarters of a mile from Kirton Church in a direction W. 30 S., a brick pit shows grey shaly clay, apparently belonging to the lower part of the Clays above the Pecten-bed. The Pecten-bed probably crosses the valley very near the Clay pit, as it appears to be represented in the stream banks at about a quarter of a mile south of the brick pit above mentioned. The exposure in the bed and banks of the stream, one mile from Kirton Church, in a S.S.W. direction, consists of a hard ferruginous, somewhat nodular, stone-bed, upon sandy ferruginous material, apparently decomposed rock, under Clay.

The following fossils were obtained from the ferruginous sandy material :—

Lima or *Limea.*
Cardinia Listeri, Stutch.
Pholadomya ambigua (var.), *Sow.*
Belemnites.

From this exposure southward to the margin of Sheet 86 the Pecten-bed is nowhere exposed in section; it is for the most part concealed by Boulder Clay and sandy *débris*; some faint indications of its feature are to be seen about half-way between Scotland Farm and Grayingham, where there are ferruginous fragments in the red surface soil, elsewhere the lines drawn for it are very hypothetical, from very slight evidence, such as change in nature of soil, &c.

The Pecten-bed is called the Top Ironstone of the Lower Lias (No. 4) by Messrs. Daglish and Howse,* who assign a thickness to it of from 4 to 5 feet.

Middle Lias Clay.

From the Pecten-bed upward to the Rhynchonella Bed, or Marlstone Rock Bed, the slope is formed by grey Clay containing bands of hard nodules in which *A. capricornus* has been found at various horizons, in the Railway cutting between Appleby and the Frodingham valley (the only section in which the Clay has been exposed from top to base).

As a rule this Clay is exposed at its junction with the overlying Rock Bed, in this respect furnishing an exact parallel to the

* *Trans. N. of England Inst. Eng.*, vol. xxiv., p. 27.

exposures of the Lower Lias Clays at their junction with the Pecten-bed.

Unfortunately, the borings at Spring Wood and north of it, which are so serviceable in giving the thicknesses of the Pecten-bed and underlying Clay, are very uncertain in their reference to the overlying strata.

In the Spring Wood boring the stratum above the Pecten-bed is described as "Blue shale," 68 feet 2 inches thick, but the overlying Rock Bed is called "sandstone," and was thought to represent the Northampton Sand (the Dogger of this district). If this bed, 5 feet 4 inches thick, really represented the Dogger the underlying shale would include both Upper and Middle Lias Clays, all mention of the intervening Rock Bed being omitted; this is a supposition too improbable to be entertained. It seems therefore nearly certain that the "Blue shale," 68 feet 2 inches thick, in this boring is the Middle Lias Clay, and that the Marlstone Rock Bed is described as "Sandstone," 5 feet 4 inches thick. Applying the same interpretation to the boring further north (bore 4) we find the Middle Lias Clay described as "Shale with cement nodules," 67 feet 3 inches thick, the overlying Rock Bed being 7 feet 10 inches thick.

Messrs. Daglish and Howse* characterise the Middle Lias Clay over the Pecten-bed (bed 4) as "shale with large cement-stone nodules," proved 160 feet thick, and valuable as a brick-clay, singularly unfossiliferous. This estimate evidently refers to the clay in more southerly parts of Lincolnshire, as they give a section (plate 9) of the beds in the Frodingham district, in which the Middle Lias is given as "shale with cement-stone nodules" 67 feet 6 inches thick.

North of Winterton Cliff House, where the Pecten-bed and Rock Bed make scarcely any outcrop features, the intervening Clay is proved by surface soil and ponds. It is exposed in pits, at about 25 chains south of Winterton Cliff House, at some distance below its junction with the Rock Bed, and, at its junction with the Rock Bed, south of the letter S in the words Santon Warren on the Map; but these exposures do not call for description.

In the Railway cutting of the Barnetby and Doncaster Line the Clay is well exposed in places; it is overlain by the Rock Bed, which is now obscurely indicated by orange, consolidated, tufaceous sand, probably a slip of surface sand stained by infiltration from the ferruginous bed. Mr. Cross speaking of this cutting says: "A Railway cutting called Santon cutting drives right into this [Middle Lias] clay, but few fossils are to be gathered."

He gives the following list of fossils obtained from the Clay in Santon cutting:—

Ammonites maculatus, *Y. & B.* = A. capricornus, *Schl.*
Belemnites paxillosus, *Schl.*
Natica, sp.
Rhynchonella variabilis, *Schl.*
Avicula inæquivalvis, *Sow.*
Cardium lobatum ? *Quenst.*
Gervillia lævis ? *Buckm.*
Goniomya (rare).

* *Trans. N. of England Inst. Eng.*, vol. xxiv., p. 27.

Lima acuticosta, *Quenst.*
Myacites, 2 sp.
Nucula complanata, *Phil.*
,, inflata, *Quenst.*
Ostrea læviuscula, *Sow.*
Pinna, sp.
Plicatula spinosa, *Sow.* (small).

At about a mile west of Appleby Station the Survey fossil-collector obtained the following from nodules in the Clay in this cutting :—

Pecten æqualis, *Quenst.*
Pholadomya ambigua, *Sow.*
Belemnites.
Ammonites capricornus, *Schl.*

From the Santon cutting southward the Middle Lias Clay is concealed, for about a mile and a quarter, by surface Sands, but its position on the slope between the hard beds, above and below it, is quite evident as far as the woods on the north side of Gokewell valley, where features are not easily distinguishable. The first exposure of the Clay worthy of mention is on the south side of the Gokewell valley just under the Rock Bed feature: from thence to Manby it is exposed, here and there, in pits and ditches, on, or near, the same horizon. As many of these exposures disclose the base of the Rock Bed it will be unnecessary to allude to all of them.

At about 66 chains north of Manton Warren House the Clay is shown under the Rock Bed in a ditch and in two clay pits below the Rock Bed feature. *Terebratula, Lima pectinoides* and a bad specimen, apparently a *Cardium*, were obtained from these exposures. Between the above and the road to Messingham the Clay is exposed in two pits.

At about 10 chains north of Manton Warren House there are two clay pits, and in their vicinity fragments of *Ammonites*, specifically indeterminable, were obtained from nodules in the Clay, at its junction with the Rock Bed, in a ditch. Between Manton Warren House and Cleatham the Clay is exposed in numerous pits, just under the outcrop of the Rock Bed.

At about a quarter of a mile north-north-west from Cleatham Grange the Clay is shown under the Rock Bed, their junction forming a rather irregular wavy line, probably due to sub-aërial agencies since the opening of the pit. In this pit 5 feet of grey Clay, with a band of nodules at from a foot to 18 inches below the Rock Bed, is shown. In nodules, at 3 feet below the Rock Bed, *Ammonites*, specifically indeterminable, were obtained by the fossil-collector in addition to the following :—

Avicula inæquivalvis, *Sow.*
Hippopodium ponderosum, *Sow.*
Pecten.
Cryptænia.

The Clay is also exposed on the west of Cleatham Grange. West of Mount Pleasant, at a quarter of a mile south of Cleatham, the Clay is exposed in a brick-pit to a depth of about 10 feet, the surface being a few feet below the Rock Bed. The Clay is of a dark bluish-grey colour, weathering toward the surface, and shaly in the lower part of the exposure; it contains hard, brown, finely-micaceous, ferruginous, sandy clay-stone nodules and brown ironstone septaria, occurring in layers.

From the nodules and septaria the following fossils were obtained :—

Avicula inæquivalvis, *Sow.*
Lima (like L. gigantea, *Sow.*).
Ostrea irregularis, *Münst.*
Pecten.
Turbo.
Ammonites capricornus, *Schl.*
Belemnites acuarius, *Schl.*
Wood (fragment).

At the commencement of the Railway cutting south-west of Kirton Station the base of the Middle Lias Clay is shown.

From Kirton Station southward, to the margin of Sheet 86 the Middle Lias Clay is generally concealed by Boulder Clay on the higher ground by drift *débris* on the slopes, and by Sand in the valleys. In this district the only exposure of importance is afforded by a brick-pit in a valley, three-quarters of a mile W. 30° S. from Kirton Church. This pit shows the lower part of the Clay, grey shaly Clay with ferruginous nodules, to a depth of from 5 to 8 feet. No determinable fossils were obtained from this pit: the Pecten-bed is exposed in a stream bed not far from it, and there is a large pit in Lower Lias Clay at about half a mile from it in the direction of Northorpe Station.

Marlstone Rock Bed.

In North Lincolnshire the Rock Bed, or top of the Middle Lias (= Marlstone), has been named "The Rhynchonella Bed" by Mr. Cross, "from the frequent occurrence in it of *R. tetrahedra*." It is described by him as "a hard light grey limestone weathering to brown, and seems to contain *Ammonites spinatus* (Brug.) towards the lower part, and *A. communis* and *A. serpentinus* in the upper."

This is the Middle Lias ironstone (Bed 3) of Messrs. Daglish and Howse (op. cit., p. 27), not rich enough for smelting near Frodingham, apparently thickening in the more southerly parts of Lincolnshire and becoming richer, largely quarried for building purposes and iron ore at Caythorpe, near Grantham. They give its thickness in the general section of the Frodingham district (op. cit., plate 9) as 7 feet 10 inches.

The Rock Bed is in places very similar to the Pecten-bed, it varies from a grey limestone to a brown ferruginous limestone or ironstone; like the Pecten-bed, it is characterised by the abundance of certain fossils, *Rhynchonella tetrahedra* and *Terebratula punctata* being the most plentiful.

In the Spring Wood Boring, as already referred to (Bore 3), the Rock Bed seems to be described as "sandstone," 5 feet 4 inches thick, and in the more northerly borehole (No. 4) a thickness of 7 feet 10 inches is assigned to it. In these borings it seems to have been mistaken for the representative of the Northampton Sand or Dogger.

After much search in the pits and other exposures of this bed in Sheet 86, south of the Humber, only one fragment of an Ammonite was obtained, and that so worn that it cannot be determined with any degree of certainty; but there are no exposures in the railway cuttings now visible. Appended is a list of fossils obtained by Mr. Cross from the Rhynchonella Bed at the east end of Santon Railway cutting (west of Appleby Station):—

Ammonites communis, *Sow.*
„ cornucopia, *Y. & B.*
„ serpentinus, *Rein.*
„ spinatus, *Brug.*
Belemnites paxillosus (large), *Schl.*
Rhynchonella tetrahedra, *Sow.*

Spiriferina (very rare).
Terebratula subpunctata, *Dav.*
Avicula cygnipes, *Y. & B.*
Goniomya, sp.
Myacites unioides, *Röm.*

The occurrence of *A. serpentinus* in the above list is remarkable. The range of *A. communis* extends to the Rock Bed, near Navenby, south of Lincoln, and in Rutland (*see* Prof. Judd's Memoir, pp. 65, 71), but I am not aware of the discovery of *A. serpentinus* in it elsewhere. A possibility of the site of the fossil having been wrongly indicated by the navvies employed in the construction of the line, or of its occurrence quite at the base of, but still in, the Upper Lias, suggests itself.

Mr. Strangways says: The Rhynchonella bed is well exposed in the village of Winteringham just at the corner of the west lane going down towards the Humber.

From a small exposure just north of the road going down to West Halton the following species were obtained in the Rock Bed by Mr. Strangways:—

Rhynchonella tetrahedra, *Sow.*
Terebratula punctata, *Sow.*
Belemnites clavatus, *Schl.*
,, sp.

C. F. S.

From Winteringham southward, to within a mile of the Barnetby and Doncaster line, the Rock Bed is scarcely discernible by feature on the slope; near Winterton Cliff House, and at half a mile to the south of it, and near Lodge Hill, it breaks the slope in slight features, but no exposures worthy of notice were met with.

On the slope above Crosby Warren, near the Ordnance height 226 on the Map, the Rock Bed makes a feature, and from this point to the south margin of Sheet 86 it is distinguishable by a feature more persistent and often more marked than that made by the Pecten-bed; but its dip-slope seldom attains to as great breadth as is frequently shown by the latter: the greatest breadth of outcrop exhibited by the Rock Bed is in the vicinity of the Barnetby and Doncaster line; on Twigmoor; and near Grayingham.

West of Appleby Station the steep slope of the Oolitic escarpment is broken by the extensive dip slope made by the Rock Bed, by the subjacent Clay occupying rather level ground, and by the Pecten-bed feature.

The Rock Bed is exposed at its junction with the underlying Clay on Santon Warren, at about a mile and three-quarters west from Appleby Station; *Rhynchonella tetrahedra, Terebratula,* and a fragment of *Ammonites* were obtained from it. The Ammonite resembles *A. semicostatus,* as far as its worn condition permits one to judge.

Near Daws Pit, at about a mile west from Appleby Station, the yellowish brashy ferruginous limestone of the Rock Bed is exposed in a ditch to a depth of from 3 to 4 feet. The following fossils were obtained from it:—

Rhynchonella, tetrahedra, *Sow.*
,, sp.
Terebratula punctata, *Sow.*
Belemnites, breviformis, *Volta.*
,, sp.

In the east part of Santon cutting orange-coloured sand, partly consolidated and tufaceous, occurs above the Middle Lias Clay; if not a slip of the overlying drift Sand, altered by infiltration through the Rock Bed, this may be the position of the bed thus referred to by Mr. Cross: The cutting "is

capped by a narrow bed, 18 inches, containing a confused mass of broken *Belemnites* and shells, together with many coprolites and much pyrites, the whole of a bright green colour." The fossils obtained by Mr. Cross have been already given (p. 50).

From the Railway southward the Rock Bed is concealed for 30 chains by Sand.

The true position of High Santon Farm is nearly half a mile south of its position on the Map; below the Farm the Rock Bed is proved by surface fragments, and it is turned up by the plough on its feature. Between the Farm and the termination of the disused branch line on Santon Common there is a small cottage (tenanted by the Keeper), at which, I am told, that a well has been sunk through 6 feet of Ironstone to the Clay. The Rock Bed and subjacent Clay are also shown in a pit near Readings Wood; from thence to Gokewell they are concealed by Sand, but the Rock Bed feature is more or less distinguishable.

From Gokewell to Kirton Lindsey the Rock Bed is marked more or less distinctly by feature, and it is exposed in several pits, of which the following are the most important:—

In a ditch section, at half a mile north from Manby, *Terebratula punctata* and *Isocardia* (like *I. minima*) were obtained from the Rock Bed.

At Manby, on the north side of the grounds, yellowish-brown ferruginous shaly limestone is imperfectly exposed.

By the road to Ashby the base of the Rock Bed is visible at the surface of a Clay pit.

On Twigmoor Warren several Clay pits, on the margin of the Rock Bed feature, disclose its rubbly ferruginous base.

At about 66 chains to the north of Manton Warren House the Rock Bed is well exposed in a ditch; *Rhynchonella tetrahedra*, *Terebratula* (*? punctata*), and *Belemnites* were obtained in comparative abundance from it; its junction with the underlying Clay is shown in the ditch.

At about 10 chains north from Manton Warren House the Rock Bed is visible in a ditch and in pits; its base is also to be seen in several of the numerous pits in the underlying Clay between Manton Warren House and Cleatham.

At about 15 chains to the southward of Manton Warren House 5 feet of yellowish-brown, shaly, ferruginous limestone is exposed in a pit, from which the following fossils were obtained:—

Ditrypa etalense, *Piette.*
Rhynchonella tetrahedra, *Sow.*
Pecten æquivalvis, *Sow.*
Avicula inæquivalvis, *Sow.*
Pleuromya.
Belemnites.

Near the above, on the south, the Rock Bed is exposed to a depth of 3½ feet in a pit; it consists of light-brown ferruginous limestone.

A pit at about a quarter of a mile north-north-west from Cleatham Grange gives the following section:—

	Ft.	In.
Surface Sand - - - - about	1	0
Rubbly ferruginous decomposed rock, splitting into small pieces; in the lower part resembling a disintegrated conglomerate, through the presence of small indurated clay-stone pellets or nodules; a similar character is noticeable in the Marlstone Rock at Manby - - 1 ft. to	2	0
Clay, with fossils, before described (p. 49). -	5	0

In the road at Cleatham, near the turning toward the Grange and Manton, the Rock Bed, consisting of light-brown crinoidal limestone and ferruginous rock, breaking into shaly pieces, is exposed at the surface.

At Cleatham, and from thence to Kirton Lindsey, the Rock Bed forms a very distinct feature. At about a quarter of a mile south of Cleatham

it is exposed in a ditch, by a path-road near the brick pit in the underlying Clay, and in a small adjacent quarry.

The quarry shows from 3 to 4 feet of thin-bedded, rubbly, ferruginous limestone. In the ditch the beds appear to be rather less ferruginous, and exhibit a tendency to split in irregular shaly pieces.

The following fossils were obtained in the quarry :—

Rhynchonella tetrahedra, *Sow.*
Terebratula Edwardsii, *Dav.*
Avicula inæquivalvis, *Sow.*
Pecten æquivalvis, *Sow.*
,, textorius, *Schl.*
Belemnites acuarius, *Schl.*
,, breviformis, *Volts.*
,, acutus, *Mill.*

Of the above, *Rhynchonella*, *Terebratula* and *Belemnites* are by far the most numerous forms.

The Rock Bed in this locality would appear to be from 8 to 10 feet in thickness.

From a small stone pit on its feature, at about a quarter of a mile south-west from Mount Pleasant, the following fossils were obtained in the Rock Bed :—

Rhynchonella tetrahedra, *Sow.*
Terebratula punctata, *Sow.*
Pecten.
Pleuromya.
Belemnites.

The Rock Bed is just visible at Kirton Station; from thence to the town its feature is well defined.

In the lower part of Kirton Lindsey beds of ferruginous limestone belonging to it are visible in a roadside ditch near the Gas Works.

From Kirton Lindsay southward for nearly a mile the position of the Rock Bed is more or less distinguishable by feature, upon which it was exposed in a small quarry at about three-quarters of a mile south from Kirton Church.

In Grayingham village the Rock Bed may be at the surface, but its outcrop feature and relation to the subjacent Clay are concealed by Boulder Clay on the west and at the cross roads on the north of the village.

At about half a mile south of Grayingham Church the ferruginous limestones of the Rock Bed were observed in a ditch running east from the road to Blyboro' (on margin of Sheet 83). For about a quarter of a mile north from the southern margin of Sheet 86 the Rock Bed is proved at the surface, on the west of the road to Blyboro'.

The meagre lists of fossils in the above notes are due to the unfavourable nature of the stone for the preservation of fossils, and to the partial character of the exposures; a similar remark is applicable to the Pecten-bed, many specimens from both having been rejected as unsatisfactory or quite indeterminable.

Middle Lias, North of the Humber.*

The railway at Everthorpe gives about the best section of these beds of any in the district. The strata here, which are lying very flat, are exposed in the cutting for a distance of over 200 yards, and consist of ferruginous flaggy limestone, with a very irregular

* From The Geology of the country between York and Hull (*Mem. Geol. Survey.*) pp. 14, 15, 1886.

top, much broken by large "pipes"; below are shales, the whole, including the soft beds at the bottom, having a thickness of about 9 feet.* South of here the outcrop curves round through the village of Everthorpe to Castle Farm† and South Cave Church, forming a good terrace to the west of the park. It crosses the lower end of the Fish Pond, being seen in the road below, and may be followed along the bank to Ellerker, where it crops out in the beck passing through the village; beyond this it gets below the level of the Sands, but has been cut into by a ditch about three-quarters of a mile to the south, and was also met with in the boring near Brantingham Grange, as mentioned below. This boring is somewhat doubtful, but it is probable that the alternating calcareous and ferruginous bands with beds of shale 16 ft. 6 in. thick should be referred to the Middle Lias.

From the neighbourhood of Ellerker the following fossils were obtained:—

Rhynchonella tetrahedra.
Terebratula Edwardsi.
„ punctata.
Belemnites breviformis.

The following is the account of the boring near Brantingham Grange as furnished by Mr. T. Allison, Guisborough:—

Section of diamond-drill boring near Mill Hill, between Elloughton and Brantingham Grange.

	Ft.	In.		
Drift, 20 ft. 6 in. — Soil and yellow sand	7	6		
Drift, 20 ft. 6 in. — Yellow clay	13	0		
Calcareous sandstone	2	0		
Blue limestone, *Cave limestone*	27	0		
Dark shale and calcareous bands	26	0		
„ „	12	0		
Grey clay shale	14	0		
Brown siliceous stone	1	8		
„ ferruginous stone	5	4	9	8
Blue „ „	2	8		
Blue shale	35	10	? Up. Lias.	
Calcareous ferruginous band	0	7		
Shale with broken shells	2	6		
Calcareous ferruginous band	0	5	16	6
Dark clay shale	7	0	? Mid. Lias.	
„ „ „ with calcareous ferruginous bands	6	0		
„ „ „	28	0		
Total	192	6		

* Messrs. W. Keeping and C. S. Middlemiss, in describing this section, make the Middle Lias rather thicker, as they include the *Capricornus* beds at the base. *Geol. Mag.*, dec. ii., vol. x., p. 216.

† There are two places of this name. The text refers to the one at Cave Castle.

CHAPTER VII.

UPPER LIAS.

South of the Humber.

The Upper Lias in Sheet 86, south of the Humber, is represented by bluish-grey shales with occasional thin lenticular limestone patches, resulting apparently from the dissolution of cementing lime from the shells of the organisms found in them. Like the Lower and Middle Lias Clays, the Upper Lias is seldom exposed at any depth below its junction with the overlying bed, which, as in these instances, consists of a ferruginous stratum; in this case the Dogger —a sandy bed from 18 inches to 4 feet thick.

Messrs. Daglish and Howse, in the section (Plate 8) appended to their paper (*op. cit.*) give 25 feet 10 inches as the thickness of the Upper Lias in the Frodingham district. Mr. Cross describes it as "a blue shale with casts of Ammonites of the falcifer type; very little explored, about 60 feet in thickness." The Upper Lias was scarcely exposed in the construction of the Barnetby and Doncaster line.

In the Spring Wood boring (Bore 3) we have, over the bed we have taken to represent the Rock Bed, a stratum of dark blue shale, 37 feet 6 inches thick, in part at least Upper Lias, it is overlain by a bed of very hard stone 1 foot 3 inches thick, which would correspond very well with the Dogger; but even supposing the Dogger to have been so soft as to have escaped mention, the hard stone could not then be higher in the series than the Hydraulic Limestone, or base of the Lincolnshire Limestone, and we should have to deduct about 12 feet for the Lower Estuarine Clays and Dogger, thus reducing the estimate for Upper Lias to 25 feet 6 inches.

In (Bore 4) the boring north of Appleby Station, above the Rock Bed, we have grey shale, 25 feet 10 inches, overlain by sandstone 1 foot 11 inches; this certainly appears to be Upper Lias under the Dogger, and its thickness rather corroborates the alternative interpretation of Bore 3 suggested above.

Mr. Cross gives no list of fossils from the Upper Lias. Those obtained by the Survey fossil collector were from the M. S. and L. Railway cutting near Kirton Station, and will be mentioned further on.

The Upper Lias is entirely concealed by Sand blown up the escarpment between Santon and Crosby Warrens. Sand also covers it on the low ground by the Railway near Low Santon; for a mile and a half southward from the road from Brigg to Bottesford; in its lower part near Reading's Wood; between Gokewell, Manby, and Twigmoor; also from Manton Warren House to Cleatham.

The Upper Lias occurs, as a rule, near the upper part of the Oolitic escarpment, cropping out at 20 feet or so below its summit. In the Low Santon valley, where the escarpment is breached, the Upper Lias occupies comparatively low ground. There are two inliers of it in the Lincolnshire

Limestone area north of the Barnetby and Doncaster Railway. The most northerly of these is in the valley near Roxby Grange, south of Winterton; the other occurs in the valley at three-quarters of a mile south of Roxby.

Mr. Strangways says: "*Ammonites serpentinus* was found in digging near the Beck, near the Keeper's House, half a mile south of Roxby, at about 4 feet beneath the surface, which was rubbly sandy stuff."

In a well at Roxby Grange, in the vicinity of the first-mentioned inlier, dark grey shales with *A. serpentinus* were encountered under about 9 feet of the basement beds of the Inferior Oolite (Dogger and Lower Estuarine beds).

The Upper Lias, or rather clay resulting from the weathering and decomposition of its shales, is exposed in the following places:—

In a pit on Sheffield Hill, by the road from High Risby west of Ordnance height 248 △ on the Map; at its junction with the Dogger.

In two clay pits north of Crosby Warren, west of Ordinance height 226 △ on the Map.

In a pit at half a mile west of Low Santon Farm, showing its junction with the Dogger.

At half a mile south of Gokewell, near its junction with the Dogger.

On the east side of the road to Raventhorpe and Manby, at half a mile south of the former, some distance below its junction with the Dogger.

In four Clay pits between Manton Warren House and Manton.

About a quarter of a mile north from Cleatham Grange in its lower part, and near the Grange in its upper part.

In ponds here and there between Kirton Station and Grayingham, and in a pit south-west of Kirton Mill.

It is visible at its junction with the Dogger, east and south-east of Grayingham.

No organic remains were obtained from the exposures of Upper Lias Clay given above; they are, as a rule, too imperfect to favour the researches of the fossil collector.

The cutting between Kirton Station and the mouth of the Tunnel in the face of the Oolitic escarpment though not affording a clear exposure, presents by far the best opportunities for obtaining fossils from the Upper Lias, the more so as it can be investigated by the spud or pick, at any horizon from top to base. After a careful search the fossil collector obtained specimens from three different horizons in the Upper Lias, which are given in ascending order as follows:—

At 3 feet above the rails at Kirton Station, just above the Marlstone Rock Bed.

Lima pectinoides, *Sow.*
Myacites (Pleuromya) unioides?, *Röm.*
Eucyclus imbricatus, *Sow.*

At 10 feet above the rails, at a distance of 14 chains from the mouth of the Tunnel.

Terebratula punctata, *Sow.*
Ammonites communis, *Sow.*
A. semicelatus, *Simpson.*
Belemnites vulgaris?, *Y. & B.*

At 25 feet above the rails, at 2 chains from the mouth of the Tunnel.

Wood.
Discina reflexa, ? *Sow.*
Gresslya.
Ammonites communis, *Sow.*, several specimens.
,, elegans, *Y. & B.* many specimens.

There is every reason to think that the Upper Lias increases in thickness as it is traced southward from the Humber; this is

apparent by its increased breadth of out-crop in the southern part of Sheet 86, and still further corroborated by its southerly development in the adjacent Sheet 83.

North of the Humber.*

The shales of the Upper Lias emerge from beneath the Alluvium a little south of Ellerker, and in the beds at this village dark laminated shales are seen, perhaps 20 or 30 feet in thickness.

In a limestone quarry, about 700 yards to the south, these beds were reached in a trial-shaft for ironstone, and a large quantity of the shale with *Ammonites serpentinus* was turned out.

The following is the account of this shaft, furnished by Mr. Allison:—

	Ft.	In.
Calcareous soil	1	0
Blue Cave limestone	18	0
Blue marl	8	0
Yellow calcareous marl	3	6
Blue shale with nodules	7	0
Total	37	6

The wellsinker's account slightly differs, but agrees better with the beck-section at Ellerker. It was—

	Ft.	In.
Limestone	14	0
Hard stone	2	0
Clay	4	0
Stone	3	0
Clay	6	0
Hard stone	1	0
Black Shale	6	0
Total	36	0

From this latter account it would appear that the "Stone 3 ft." is the Hydraulic Limestone, and the "Hard Stone 1 ft." the base of the Oolites.

About here the outcrop of the Lias sinks beneath the sands, and is not again seen, although it has been reached in the several trial-holes for ironstone between here and Brough.

At the point where the footpath to Ellerker crosses Whin Moor Lane, a shaft was sunk 17 feet in sand and blue clay; no particulars of this shaft were kept, but, judging from the outcrop of Middle Lias ironstone near here, it must have nearly gone through the Upper Lias shale; as also probably did the next shaft, which is 400 yards to the south, and gave—

	Ft.	In.
Sandy soil	3	0
Stony clay	1	0
Bottom part of blue Cave Limestone	1	6
Blue shale with nodules of cement stone	17	0
Total	22	6

* By Mr. C. Fox-Strangways.

In this section the "Blue Cave Limestone" represents the Basement Bed of the Oolites, as the site of the shaft is certainly below the base of the Cave Limestone, and very near the base of the Oolites altogether.

The diamond-boring near Brantingham Grange gives 35 ft. 10 in. of blue shale below the Oolite, if we are right in this interpretation of the section. In Brough a boring at the back of the Railway Hotel is said to have reached "Sandstone" at 90 ft., while one at the Station is 18 ft. in clay, and then "Greystone," and one at Castle Hill is 40 ft. to "Stone," but there is so much discrepancy about these Brough borings that they are of little value.

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* From The Geology of the Country between York and Hull. *Mem. Geol. Survey.* pp. 16–18, 1886.

CHAPTER VIII.

THE LOWER OOLITES.

The Lower Oolites in Sheet 86 present features of considerable local interest, the North Lincolnshire type being apparent up to the Humber flats, whilst emerging from beneath them we find, on the north of that river, the incoming, in a very attenuated form, of that type which characterises the Yorkshire area, namely, the development of sands and sandstones, and the restriction of the limestones, which form the main mass of the group south of the Humber, to definite horizons of comparatively small thickness, making convenient breaks in the great development of estuarine beds in which they occur.

The Lower Oolites consist of two main groups, viz.: The Inferior Oolite; the Great Oolite Series.

Superficially the area occupied by the Great Oolite Series, in Sheet 86, is very small, through the northerly attenuation and disappearance of one of its divisions, and owing to its concealment by the Alluvium of the Ancholme for a considerable distance along the strike.

Inferior Oolite.

The Inferior Oolite is distinguished in Sheet 86 by lithological differences in the limestones, constituting the main mass of the series, sufficiently marked and restricted to stratigraphical limits to enable us to separate them by boundary lines.

The classification of this group south of the Humber is as follows:—

- Inferior Oolite
  - Lincolnshire Limestone.
    - Hibaldstow Beds.
    - Kirton Beds.
  - Basement Beds
    - Hydraulic Limestone.
    - Lower Estuarine Sand and Clay.
    - Dogger.

The divisions of the Basement Beds cannot be separated by geological boundaries, as the series forms a narrow band on the upper slope of the Oolitic escarpment, and its total thickness is insignificant, probably nowhere exceeding 26 feet. The Lincolnshire Limestone, on the contrary, affords a marked contrast in the character of its upper and lower beds, so that a geological boundary line can be drawn separating the Hibaldstow and Kirton beds from the Humber southwards. This boundary cannot, however, be traced into Sheet 83 on the south, owing to the merging of these distinctive characteristics, and to the impossibility of restricting the variations in the Lincolnshire Limestones to definite stratigraphical horizons.

The order of description adopted in the detailed notes on the Lower Oolite subdivisions is from south to north.

BASEMENT BEDS.

The upper bed of the Basement Oolites in Sheet 86 consists of a hard fine-grained limestone, which seems to die out and become merged in the lower beds of the Kirton Series in Sheet 83; in Yorkshire this is called the "Hydraulic Limestone"; it rests upon bluish clay or shale with sand irregularly associated (the Lower Estuarine beds), beneath which is the ferruginous sandstone called the "Dogger."

Mr. Cross* comments on the difference exhibited between the fossils from beds at the bottom of the Inferior Oolite at Santon and those obtained from the overlying beds. He calls the former the Santon Oolites and describes them as "a soft dark-coloured ferruginous bed, and an oolitic limestone bed above it." These beds I take to be above the Hydraulic Limestone in the section at Low Santon Lane; they belong to a type which can be best studied between Winterton and Roxby, and at Raventhorpe on the Oolitic escarpment. Here, however, we are confronted by the consideration of the value of the boundary between the Kirton Beds and Basement Beds. It will be seen that the beds for 5 feet above the Hydraulic Limestone in the Cleatham Hill section† are identical in character with those immediately below it; and, further south, in Sheet 83, the position of the Hydraulic Limestone is occupied by a series of rubbly limestones in which no distinctive bed has been found. From this it would appear that, although we are justified in marking our stratigraphical boundary by the Hydraulic Limestone, which, owing to its superior hardness and fine grain, can be detected, yet, palæontologically, the junction would be some feet above the Hydraulic Limestone, to include beds of the Raventhorpe type in the Basement Series.

In the road to Northorpe Station the outcrops of the Hydraulic Limestone and Dogger are marked by features, the gentler slope between them being made by the softer Estuarine Beds, which are not exposed. On the south of the road, at the letter *i* of the word Grayingham, on the Map, the Dogger is exposed at a spring given out at its junction with the Upper Lias Clay; the ground is often marshy at this horizon. The exposure presents one foot of rubbly, red-brown, fossiliferous, decomposed rock, upon a harder bed, of which 6 inches are visible. The following fossils were obtained from the rock:—

Galeropygus agariciformis, *Forbes.*
Cardium (cast, small).
Corbis rotunda, *Walton.*
Cypricardia.
Isocardia.
Modiola sowerbyana, *D'Orb.*
Myopsis.
Pholadomya Heraulti, *Ag.*
Thracia.

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* *Quart. Journ. Geol. Soc.*, Vol. xxxi., p. 121, 1875.
† See Section given on next page.

In the following notes beds which really belong to the Lincolnshire Limestone are described where the exposures afford indications of the position of the Hydraulic limestone.

Mr. Nicholson of Willoughton Grange had a well sunk at Grayingham Warren farmyard, in which, he tells me, that sandy shale was encountered under about 2 feet of limestone. This would seem to indicate sand beds of the Lower Estuarine Series, but from the site of the sinking it is more probable that the beds, penetrated to a depth of about 24 feet, belong to the Kirton type of the Lincolnshire Limestone.

By the road south of Kirton Mill, at about 30 chains distant a bed of compact grey limestone, weathering light brown, is exposed; it marks the horizon of the Hydraulic Limestone. Further south a quarry on the east side of the road shows a thick bed of limestone with coarse irregular oolitic grains in places; it is overlain by a soil of light brown loam with nodular fragments of limestone, 3 to 4 feet in thickness. The limestone bed is even, and, (including a thin top bed) 2 feet in thickness, it rests upon a 4-inch band of brown and grey loamy shale with numerous small fossils, chiefly *Ostrea;* the bottom of the quarry exhibits the compact Hydraulic Limestone under the shaly band; the beds conform in dip to the surface of the ground.

South of the above, on the south side of the turning towards Redbourne, at the cross roads, compact grey limestone intersected by numerous lateral cracks is exposed to a depth of 3 feet; this is above the Hydraulic Limestone. A larger quarry, near the above, on the west side of the road to Kirton, shows similar limestone with a capping of well-worn Oolitic gravel. The Hydraulic Limestone does not appear to be exposed in these pits; it is, however, evidenced by feature, by the turning towards Northorpe Station and from thence southwards.

From Kirton Mill to the section between Cleatham and Mount Pleasant no definite evidence of the character of the Basement Beds of the Oolites is obtainable. Between Mount Pleasant and the mouth of the Tunnel a boss of rock, apparently *in situ*, seems to mark the position of the Dogger on the slope; it is further proved by ferruginous fragments on the ploughed slopes, near the Mill, at a short distance north of Kirton. On the north side of Kirton a block of ferruginous sandstone by a pond, near the road to the Station, also attests the vicinity of the Dogger. The Lower Estuarine Clays and Hydraulic Limestone are scarcely indicated on the surface between Mount Pleasant and Kirton.

Between Cleatham and Mount Pleasant a bye-road, leading up the escarpment from a brickyard in the Middle Lias Clays, affords a ditch section of Marlstone, above which the Upper Lias Clays are not exposed; but near the top of the escarpment the Basement Beds of the Oolites, from the Dogger upwards, are more continuously visible than in any other part of the escarpment embraced in Sheet 86, south of the Barnetby and Doncaster Line. The beds, given in descending order, are as follows:—

Cream coloured, broken, shaly mudstones, similar to those below the Hydraulic Limestone -	5 feet.
Tough, pale grey limestone, in part siliceous and with oolitic grains, containing very small fossils, representing the Hydraulic Limestone - -	2 ft. 3 to 6 ins.
Impure argillo-arenaceous brashy and shaly stone -	5 feet.
Whitish sand-rock, exposed in the upper part of the road-cutting, apparently just above the Dogger, and passing under, or dovetailing into, bluish-grey shales, for the most part concealed by grass; both together constituting the Lower Estuarine Series, and apparently attaining a thickness of - - - - -	12 feet.
Dogger, represented by tough, reddish-brown, fine-grained, ferruginous sandstone, very partially exposed, apparently about - - -	5 feet thick.

No further section is seen till the road to Kirton is reached, where the Kirton Beds are exposed in a quarry.

By the road to Cleatham down the Cliff (Oolitic escarpment), yellowish-brown, soft, broken, ferruginous sandstone, apparently about 8 feet in thickness, represents the Dogger; above it whitish sand-rock, resembling that in the foregoing section, is exposed to a depth of about 5 feet, representing in part the Lower Estuarine Series; it is capped by an old river gravel of worn Oolite stones under brown loam, but the overlying beds appear to be similar to the brashy beds associated with the Hydraulic Limestone in the section just given.

West of Stainewell Warren, on the south of the Farm (north of the word Manton on the Map), a quarry affords the following section:—

	Ft.	In.
Drift sand	5	0
Compact grey limestone with scattered oolitic grains, in two beds	0	10
	0	3
Pale buff-brown shale with small *Ostrea*	0	6
Hard, even-bedded, compact limestone (Hydraulic Limestone).		

The continuity of the Basement Beds of the Oolites, north of the above, toward Raventhorpe, where the cliff is masked by Sand, can be proved by feature; by the occasional presence of ponds held up by the Upper Lias Clays below; and, also, by the patches of the lower beds of the Lincolnshire Limestone exposed in quarries near the edge of the escarpment.

In the lane near Manton, on the east, a thick bed of ferruginous sandstone (Dogger) is exposed; the Dogger is also visible on the slope above Manton Church. At the bend in the lane south of Manton Church the Dogger is shown, and, above it, 8 feet of Lower Estuarine clays.

The lower beds of the Oolites on the descent of the Cliff (Oolitic escarpment) near Raventhorpe, above the Clays of the Upper Lias, consist of broken, ferruginous, soft, brownish sandstone, representing the Dogger, seen here and there for 28 yards; it is overlain by white sand (under a patch of Oolitic gravel) apparently dovetailing into blue shaly clay. The white sand and clay are Lower Estuarine Beds, as on the hill above Cleatham.

The Hydraulic Limestone is not exposed in the immediate vicinity of the above section; it may be represented by fine-grained, pale grey limestone, exposed to a depth of 18 inches, under 2 feet of thin-bedded, drab-grey, sandy limestone (with small yellowish patches and oolitic granules), in a quarry near the edge of the escarpment.

A few chains to the south of this quarry, pale grey, nodular, and rubbly limestones are exposed to a depth of from 2 to 3 feet, resting upon pale drab, loamy shale. In this section the shaly beds would appear rather to represent the interstratification usual in the lower beds of the Kirton sub-division than the upper part of the Lower Estuarine Beds, so that they are most probably above the Hydraulic Limestone.

The Basement Beds of the Oolites are concealed at three-quarters of a mile south of Raventhorpe for 10 furlongs by Blown Sand, which masks the face of the escarpment, and extends over a considerable tract between Far Wood and Stainewell Warren.

Mr. Strangways carries on the description in the northern part of the district, as follows:—

The Basement Beds, which seem to be equivalent to the lowest part of the Estuarine Series of Yorkshire, or as much of that formation as lies below the Millepore Bed of the coast and the Oolite of Cave, including the Dogger and Hydraulic Limestone, occupy a narrow band along the cliff edge, extending in a few cases further east over the dip-slope, where the limestone above has been removed by denudation.

These beds probably have a thickness of from 20 to 30 feet; but, although there are several boreholes and well sections through them, it is impossible to make out from the descriptions how much should be included in these beds and how much in the limestone above.

The Basement Beds are composed, for the most part, of shaly calcareous beds and thin sandstones, which at the base become very ferruginous. The lowest beds are exposed in the ditches near Ganstons House, and are very ferruginous, much resembling some beds of the Dogger in Yorkshire; the higher beds were seen in field-drains about Roxby and Winterton, and in the road-cutting beneath the railway at Santon, where their junction with the Limestone above is well exposed.

In the road-cutting above alluded to the beds have an abnormally high dip for this series. The Hydraulic Limestone crops out in the road; it is separated by broken rubbly limestone, with an arenaceous appearance, from Lower Estuarine clays exposed on the west side of the road: the Dogger is not shown. The Hydraulic Limestone is overlain by rubbly oolitic limestones.

These beds, consisting of hard sandstones with shaly bands, were also exposed in digging the foundations of a new chapel, at Winteringham, where they form the steep part of the bank, crossing the village till they dip beneath the Alluvium to the north-east.

On the Yorkshire side of the Humber these beds reappear from beneath the Alluvium, a little to the north of Brough, and may be traced as a narrow strip beneath the low escarpment formed by the limestone in the neighbourhood of Ellerker and South Cave.

They are much thinner about here than in Lincolnshire, for in the stream at Ellerker, where there is a continuous section, there are only about 6 to 8 feet of beds between the Hydraulic Limestone and the Upper Lias Shales. In several boreholes and trial shafts, details of which are given in the Memoir descriptive of this country, these beds appear to vary in thickness from about 11 to 25 feet. They consist of marly shale with a thin siliceous sandstone with fossils at the base.*

C. F. S.

THE LINCOLNSHIRE LIMESTONE.

The distinction between Hibaldstow and Kirton Beds applies only to that part of Sheet 86, which is south of the Humber.

The Hibaldstow Beds are so called because they are well exposed at the village of that name.† They form the uppermost division of the Lincolnshire Limestone from Waddingham northwards to the Humber. They consist of buff or cream-coloured Oolites, the oolitic structure varying from fine and well rounded, to coarse, irregular granules, sometimes of large size. These beds do not appear to be ever intercalated with clay or loam. Their thickness is probably not much more than 20 feet.

The Kirton Beds are so called from the town of Kirton Lindsey, in the vicinity of which they present their most marked lithological

* Mem. Geol. Survey, Geology of the Country between York and Hull, p. 19; 1886.

† In the first issues of the Map (Sheet 86) and in the Memoir on Sheet 83 (p. 44) these beds were termed *Ponton Beds*; but as the characteristic fossiliferous Ponton Oolite cannot here be identified it has been thought better to use a local name in this Memoir. It is, however, probable that the upper beds of the Great Ponton cutting represent those here spoken of as Hibaldstow Beds. The correlation of the lower beds of the same cutting with those of Sheet 86 is less certain, as some of them may represent the upper part of the Kirton Beds.

characteristics, and are of the greatest economic importance. These consist of grey limestones, interstratified with beds of loam and clay; near Kirton they contain fine grained nodular limestone bands, which are ground up for cement. In their lower portion the Kirton Limestones, which are partially oolitic, become frequently like the Hibaldstow Beds, weathering yellow and exhibiting oolitic structure throughout.

The Basement Beds form the upper part of the face of the Oolite escarpment, the Kirton Beds occupying its crest and the upper part of its dip-slope; they pass under the Hibaldstow Beds, which usually make a slight junction-feature at their very sinuous boundary line, and occupy the lower part of the dip-slope, terminated eastward by the Alluvium between the Barnetby and Doncaster Line and Hibaldstow and by the gravel flats south of Hibaldstow.

Between Waddingham and Grayingham Warren Farm we find limestones, referred to under the head of Hibaldstow Beds, which are similar in colour and texture to beds commonly found in the Kirton series, yet they pass directly under the Great Oolite series. The Hibaldstow Beds, which are so distinctly traceable south of a line between Grayingham Warren Farm and Waddingham, seem to preserve their very oolitic aspect only in their lower beds, and cannot be traced southwards as a distinct lithological division. The Kirton Beds lose their distinctive characters south of Grayingham Warren. By these changes we find as we proceed southward a more and more homogeneous series of beds composing the Lincolnshire Limestone.

The boundary between the Hibaldstow and Kirton Beds is very irregular, but as far as Sturton, near Scawby, it may be said to follow the Roman Road, the Kirton Beds running eastwards in the valleys and the Hibaldstow Beds spreading west on the higher grounds. From Sturton to Wressle Houses, near Broughton, the Hibaldstow Beds occur on the lower part of the dip-slope on the margin of the Alluvium, the Kirton Beds running as far east as the Alluvium east of Scawby and Sturton. Toward Appleby both divisions are largely masked by Sand.

In the Appleby and Winterton district the Kirton Beds cover a much larger surface than the Hibaldstow Beds, the relations of divisions being complicated by faults on the Santon and Risby Warrens.

Mr. Strangways refers to the part of Sheet 86 north of the Humber as follows:—

In Yorkshire the Lincolnshire Limestone has not been divided but is mapped as one deposit. The main mass of the rock is a good oolitic limestone, massive and blue-hearted, but towards the base it becomes very shaly; the change is, however, so gradual that no line can be drawn. In the account of the boring near Elloughton there are 29 feet 6 inches of limestone and 38 feet of calcareous shales, but the cores which were brought out showed that these calcareous shales were really limestone in a soft, unconsolidated state, very similar to the same beds in the lower part of the Kirton Quarry

The limestone is exposed in the bed of the Humber, at low water, at Brough Scalp, but is not seen north of this again for about a mile, being entirely concealed by the thick superficial deposits in the neighbourhood of Brough. About a quarter of a mile north of this village the limestone has been extensively quarried and forms a good feature by Ellerker and South Cave to Newbald and Santon in the next map, where it becomes overlapped by the Chalk.

C. F. S.

The following lists of fossils from the Lincolnshire Limestone beds are given (p. 124) by Mr. Cross. The last list may be from the Hibaldstow Beds:—

Santon Oolite.

Marly bed below.

Ammonites, one specimen allied to A. Truellii, *D'Orb.*
Belemnites.
Modiola ungulata, *Y. & B.*
Pholadomya fidicula, *Sow.*
Ceromya bajociana, *D'Orb.*
„ cornuta, n. sp.
Ostrea mima, *Phil.*
Pecten lens, *Sow.*
Hinnites abjectus, *Phil.*
Gervillia acuta, *Sow.*
Pinna cuneata, *Sow.*
Trichites nodosus, *Lycett.*
Glyphæa.

Limestone above.

Nerinæa sp. (near to N. Cotteswoldiæ, *Lyc.*).
Turbo, n. sp.
Trochus, n. sp.
Neritopsis, n. sp.
Natica (Euspira).
Cerithium.
Alaria.
Pholadomya fidicula, *Sow.*
„ Heraultii, *Agass.*
Ceromya bajociana, *D'Orb.*
Modiola cuneata, *? Sow.*
„ Leckenbyi, *? Lyc. and Mor.*
Trigonia hemisphærica, *Lyc.*
„ Phillipsii, *Lyc.*
Opis cordiformis, *Lyc.*
Corbicella complanata, *Lyc.*
Astarte elegans, *Sow.*
„ pumila, *Sow.*
„ squamula, *D'Arch.*

Astarte recondita, *Phil.*
„ minima, *Sow.*
„ divaricata, n. sp.
Cypricardia bathonica, *D'Orb.*
Cyprina trapeziformis, *Römer.*
Corbula.
Cardium, sp. (like cognatum, *Phil.*)
„ striatulum, *Sow.* [? C. Buckmani, *Lyc. and Mor.*]
Isocardia cordata, *Buckm.*
Nucula Hammeri, *Def.*
„ variabilis, *Sow.*
Cucullæa oblonga, *Sow.*
„ ornata, *Phil.*
„ Rolandi, n. sp.
Myacites.
Gresslya?
Ostrea mima, *Phil.*
Pecten aratus, *Waagen.*
„ lens, *Sow.*
Lima rigidula, *Phil.*
„ large sp. (like L. Hermanni).
Hinnites abjectus, *Phil.*
Gervillia acuta, *Sow.*
Macrodon hirsonensis, *Lyc. and Mor.*
Serpula.
Echinus.
Cidaris.
Pentacrinus (dwarf sp.).
Small corals.

Then follows a list of Lincolnshire Limestone fossils from the overlying beds.

Ammonite, one large specimen only known, Humphriesianus type.
Pleurotomaria pallium, *D'Orb.*
„ armata, *Münst.*
„ sp.
Natica adducta, *Phil.*
„ leckhamptonensis, *Lycett.*
„ large sp. (cast).
N. (Euspira) (cast).
Purpurina.
Nerinæa Jonesii, *Buckm.*
Cerithium (cast).
Turbo oppellensis, sinistral sp., *Lyc.*
Eulima (cast).
Patella rugosa, *Sow.*
Dentalium.
Modiola ungulata, *Y. & B.*
„ Lonsdalei, *Lycett.*
„ Leckenbyi?, *Lyc. and Mor.*

Modiola aspera, *Sow.*
Pholadomya fidicula, *Sow.* (very rare).
„ Heraultii, *Agass.* (common).
Homomya crassiuscula, *Lyc. and Mor.*
„ gibbosa, *Sow.*
Goniomya V-scripta, *Sow.*
Cardium.
Unicardium.
Cypricardia acutangula, *Phil.*
Astarte rhomboidalis, *Phil.*
Trigonia hemisphærica, var. (dwarf), *Lyc.*
Arca pulchra? *Sow.*
Lucina bellona, *D'Orb.*
Lithodomus (cast of).
Lima bellula, *Lycett.*
„ proboscidea, *Sow.* [L. pectiniformis, *Schloth.*]
„ lævis, n. sp.?
„ sulcata, n. sp.?
„ duplicata, *Sow.*
Hinnites abjectus, *Phil.*
Pecten lens, *Sow.*
„ aratus, *Waagen.*
„ articulatus, *Schl.*
Gervillia acuta, *Sow.*
Perna quadrata, *Phil.*
Pteroperna.
Pinna cuneata, *Phil.*
Ostrea gregaria, *Sow.* (common).
Terebratula submaxillata, *Mor.*
Waldheimia ornithocephala, *Sow.*
Rhynchonella quadruplicata? *Dav.*
„ Crossii, *Walker.*
Serpula.
Cidaris (rare).
Echinus (rare).
Corals (obscure).

KIRTON BEDS.

From the south margin of Sheet 86 to Kirton Mill, this sub-division is partially covered by sandy drift soil, but the upper and lower beds are well exposed east of Grayingham.

Between Grayingham Warren and Wedge Wood, in a quarry two-thirds of a mile north-north-east of the former, fossiliferous grey limestones, belonging to the upper part of the Kirton Beds, are exposed. The following fossils were obtained:—

Terebratula globata, *Sow.*
„ maxillata, *Sow.*
Cypricardia.
Lucina bellona, *D'Orb.*
Pinna.

At the cross roads east of Grayingham, south of Kirton, beds of compact grey limestone (apparently at the base of the Kirton Beds, and just above the Hydraulic Limestone) are exposed in two quarries, described in the notes on the Basement Beds. The following fossils were obtained from them:—

Wood (a fragment).
Pecten lens, *Sow.*
Lima duplicata, *Sow.*

At a mile and a half east of Kirton Mill, in a ditch on the east side of the Roman Road south of its junction with the high road to Redbourne, the upper part of the Kirton Beds is exposed to a depth of 5 feet, consisting of grey limestones weathering pale brown, and resembling those of Broughton and Wressle Houses; the Hibaldstow Beds are evidenced in the fields by soil and surface fragments, and *in situ* in a pit, about 12 chains south of the ditch.

By the road to Redbourne, at about a quarter of a mile from Kirton, a large quarry exposes the following section, from the surface downward:—

		Ft.	In.		In.
	Brown top-soil	0	6		
	Rubble of whitish, partly oolitic, limestone fragments in light brown soil	4	0		
	Tough, grey, rubbly-fractured, fossiliferous limestone, partly oolitic	2	6		
	Yellowish-brown sandy parting	0	5		
Cement stones.	Tough grey limestone, partly oolitic	1	0	to	5
	Dark grey shaly clay	0	8	to	11
	Pale bluish-grey limestone, surface irregular	1	1		
	Dark grey shale parting	0	1	„	2
	Grey argillaceous limestone	0	3	„	4
	Dark grey shale parting	0	1	„	2
	Irregular pale bluish-grey limestone	0	6	„	9
	Dark grey shale	0	3	„	5
	Pale grey argillaceous limestone	0	8	„	9
	Shaly parting	0	1	„	3
	Tough grey limestone	1	0		
	Brown shaly parting, passing into soft, yellowish-brown decomposed limestones	0	4	„	5
8 feet.	Pale yellowish-brown oolitic limestone with irregular granules	0	11		
	Pale brownish or cream-coloured oolitic limestones, the grains being disseminated in patches throughout in 10 rather even beds. A piece of brown drift-wood was found in the thickest bed.	0	4		
		0	5		
		0	6		
		0	9		
		0	7		
		1	6		
		0	6		
		0	6		
		1	0		
		1	0		

In other parts of the quarry the cream-coloured, or light brown, hue is shown to be the result of weathering, the freshly-quarried basement beds being of a bluish-grey colour, with oolitic grains very sparsely disseminated through them. Within 4 feet of the floor of the quarry occasional fragments of brown drift wood occur in the beds. Traces of plants, which cannot be indentified, and *Serpula* have been obtained in the quarry. The dip in the south part of the quarry is E. 20° S., but it cannot be relied upon, as in a neighbouring quarry, wherein the upper part is alone

exposed, the beds appear to be horizontal. The following fossils were obtained from the large quarry:—

In the upper part of the quarry above the Cement-stones:
- Pseudodiadema depressa, *Ag.*
- Terebratula.
- Avicula.
- Gervillia, or Pteroperna.
- Lima duplicata, *Sow.*
- Lucina? burtonensis, *Lyc.*
- Ostrea gregaria, *Sow.*
- Pecten lens, *Sow.*, many specimens.
- „ annulatus, *Sow.*
- „ aratus *Waagen.*
- Nerinæa Voltzii, *Desl.*

Below the Cement-stones:
- Small fragments of Wood.
- Fucoid.
- Crustacean claw.
- Corbis Lajoyei, *D'Arch.*, var. cingenda, *Lyc.*
- Corbula?
- Myacites jurassi, *Brong.*
- Pecten lens, *Sow.*
- Pinna lanceolata, *Sow.*
- Belemnites.

Near Kirton *Thamnastræa defrancíana*, Mich., was found in a surface fragment, apparently belonging to the lower beds of the Kirton series.

Between Kirton and Redbourne, at more than half a mile north-north-west from Springcliff House, a shallow quarry shows 1 foot to 18 inches of shaly limestone (containing *Pholadomya*, &c.) upon rubbly nodular grey limestone. The nodular limestones are at the surface on the north and north-west of the quarry.

The following is a rough estimate of the section at the mouth of the Tunnel nearest Scawby, as viewed from above:—

	Ft.	In.
1. Pale-buff and brownish, shaly clay or loam	5	0
2. Limestone	1	0
3, 4, 5, 6. Shaly limestones averaging 6 inches in thickness; Rather even-bedded limestones	3	0
	2	6
Shale or clay parting.		
Nodular limestones with shaly and clay partings in rather thin beds - 3 ft. to	4	0
Irregular limestones, apparently	10	0
Shaly and clayey matter with nodular beds of limestone	5	0
Limestone - 1 ft. to	2	0
Shale at base of cutting.		

The numbers prefixed show the probable connexion of the beds with those in the quarries about to be described.

By the Railway between Kirton and Scawby Stations, west of Gainsthorpe, the Kirton Beds are finely exposed, both in the cuttings, which are inaccessible in the upper and middle parts, being nearly vertical, and in a large quarry, which furnishes material for the manufacture of a valuable hydraulic lime, sold as "Blue Lias lime."

The Cement-stones consist of dense, rubbly, nodular, argillaceous limestones, with irregular partings of clay and shaly matter, some of which have been used for brickmaking, and burn to a white brick. The thickness of the Cement-stones is about 9 feet, their place in the quarry will be shown in the following detailed section, in which their component beds are given;

but as these are of an irregular character, the thicknesses of the several beds given merely apply to the spot where they were measured.

		Ft.	In.
On the surface in one part of the quarry, and over the adjacent Railway cutting, a Drift of brown sand with small broken fragments of Oolite occurs, attaining a thickness of		3	0
1. In the Railway cutting and in part of the quarry a bed of whitish and pale drab shaly clay is exposed, attaining a thickness of		6	0
2. Hard even bluish-grey limestone, jointed irregularly		1	2
3. Pale brown, rubbly, nodular, argillaceous limestone, passing into shale		1	6
4. Brown shale, decomposed shaly limestone		0	6
5. Hard, rather even-bedded, fine, grey, limestone, in three or four beds, of which the uppermost furnished *Lima proboscidea* and *Homomya gibbosa*	2 ft. to	2	3
6. Dark bluish-grey shale and decomposed shaly limestone, with thin impersistent beds of limestone, containing numerous fossils		1	6
Cement-stones, 8 ft. 3 in. — Top of Cement-stones, dense grey limestone	8 in. to	1	0
Blue clay	6 in. to	0	8
Irregular, rubbly, argillaceous limestone		1	0
Dark blue shaly matter		0	6
Bluish-grey clay with nodular limestone		0	6
Rubbly argillaceous limestone		0	6
Dark bluish-grey shaly matter, passing into impure limestone and clay	6 in. to	0	8
Rubbly, grey, argillaceous limestones, splitting into very irregular beds		1	6
Dark grey shaly matter, passing into clay with nodular limestone		0	6
Irregular grey limestone		1	9
Hard, even-bedded, fossiliferous, grey limestone, in two beds	from 2 ft. to	2	10
Hard, even-bedded, grey limestone		1	0
Do. lowest bed exposed		1	10

Above the Cement-stones *Pholadomya Heraulti*, *Homomya gibbosa*, and *Lima pectiniformis* were obtained.

By the Roman Road, south of the Lodge by the Railway between Kirton and Scawby Stations, the following section was disclosed, downward from the surface:—

	Ft.	In.
Brown and drab soil	2	0
Irregular, shaly, tough limestone, decomposed to a drab hue, containing small fossils	0	6
Hard grey limestone, with occasional iron-shot oolitic grains, also in limestones below	0	11
Parting of decomposed yellowish shale and nodular limestone 1 in. to	0	3
Hard, rubbly, grey limestone, in two or three beds	1	5
Decomposed shaly ferruginous bed, with large irregular oolitic granules, passing in places at its base into tough limestone	0	9
Very hard grey limestone	1	1
Decomposed brown shaly parting	0	6
Very hard, compact, grey limestone, with veins of oolitic grains, and small fossils, exposed to a depth of	1	6

The beds dip E. 10° S. at about 2°, a dip of 5°, taken on a bed surface not being trustworthy.

Between Kirton and Scawby Stations, at three-quarters of a mile to one mile from the latter, on the north of the Railway, fragments of yellowish-brown ferruginous stone and rubbly, grey, siliceous limestone, are plentiful on the surface of the lower ground. The low hills are composed of Hibaldstow Beds, pale buff shaly Oolites, these are shown in a road-cutting (partially exposed on either side of the Railway bridge crossing it) to overlie siliceous and nodular limestones with clayey partings, which, therefore, represent the uppermost part of the Kirton Beds.

Near this spot a boring for ironstone was undertaken by Mr. Dallison, as I was informed by Mr. Bradley, of Scawby Station Inn, but was abandoned at a considerable depth.

A record of this boring, furnished by Mr. Charles Hett, will be found in Appendix II. (p. 212).

Between the turnings to Manton and Cleatham Grange, at about 15 chains from the edge of the escarpment, nodular, rubbly, grey limestones are exposed in a small pit; at about three-quarters of a mile to the east, near the path on the south of Stainewell Warren, a small exposure of similar beds was observed.

Between these exposures there appears to be a patch of oolitic rock, representing the base of the Hibaldstow Beds, but from the prevalence of oolitic beds in the lower part of the Kirton Beds and the absence of exposures furnishing reliable dips it might possibly belong to the latter subdivision.

A larger patch of Oolite, also shown as an outlier of Hibaldstow Beds on the north of the Tunnel, might give rise to a similar doubt.

By the road to Kirton, at about a quarter of a mile north of the Tunnel, a quarry exposes 15 feet of pale bluish-grey shaly clay, rather loamy; it contains an even bed of tough limestone about a foot in thickness, and, near the base of the exposure, which is masked by talus, nodular impersistent bands of limestone occur. From the rubble which conceals the lower part of the quarry, these beds appear to rest upon dark bluish-grey, impure, fossiliferous, shaly-splitting limestones. Oolitic *débris* at the surface rests upon the shaly clay.

In the limestone refuse concealing the lower part of the quarry and from the shales the following fossils were obtained:—

Montlivaltia.
Thecosmilia gregaria, *McCoy.*
Serpula socialis, *Goldf.*
Gervillia acuta, *Sow.*
Lima punctata, *Sow.*
Myacites.
Ostrea gregaria, *Sow.*
Pholadomya Heraulti, *Ag.*
Pecten articulatus, *Schl.*
Quenstedtia oblita, *Phil.*
Cylindrites.
Natica (Euspira) canaliculata, *Lye. & Mor.*
Turbo gemmatus, *Lye.*

As no sections or exposures are afforded between this quarry and the section of the Basement Beds near the top of the escarpment, a quarter of a mile west of it, from the slight dips to the east in both exposures it would appear that the concealed beds represent a thickness of from 25 to 30 feet, which would place the beds in the quarry at or near the top of the Kirton Beds and would favour the idea that the oolitic patches as shown on the Map are outliers of the Hibaldstow Beds.

At the letters *nt* of the words Sturton Plan*t*ation on the Map a pit 8 feet in depth has been excavated for the purpose of claying the sand soil of the surrounding field. For 3 feet from the surface (sand soil) weathered fragments of compact grey limestone irregularly dispersed in clay rest unevenly upon pale greenish-grey clay and loam with fragments of rubbly limestone; these are probably disjointed beds of the Cement-stone series. Grass-growth and talus conceal the sides of the pit from 4 to 5 feet from the bottom.

On the south side of the road towards Manton Warren House, near the south-east corner of Sturton Plantation, 4 feet of coarsely oolitic limestones are exposed in a quarry. The limestone is penetrated by pipes filled with clay, indicating no doubt the former presence of an overlying clayey bed. The limestones may be represented by the top rubble in the neighbouring pit mentioned above; they are probably on the horizon of the beds immediately above the Cement-stones in the quarry near Kirton on the east.

On the south side of Sturton Plantation, between the roads to Scawby and Stainewell, clay is exposed in a large pit; the overlying bed is shown in an adjacent quarry and consists of limestone, resembling and probably the same as that in the quarry at the south-east corner of the Plantation.

On Manton Warren, near the top of the Oolitic escarpment by the road to Messingham, a pit, 3 chains across, shows the lower part of the Kirton Beds, consisting of limestones, partly nodular and rubbly, with oolitic structure in places, and also in places very ferruginous; these beds are on a lower horizon than the Cement-stones of Kirton.

Through the Sand drift on the south of the road to Messingham several large quarries have been opened, exposing about 5 or 6 feet of buff limestones with oolitic grains, in some cases close together and in patches but as a rule scattered throughout the rock. The beds are split up by thick irregular shaly joints in places; drab shaly loam forms the uppermost bed and occasionally contains near the surface fragmentary relics of a bed of nodular limestone.

From one of these quarries, at about half a mile north-east from Manton Warren House, *Montlivaltia* was obtained.

At and near the letter *S* in the words *S*turton Plantation on the Map there are two quarries in which beds, probably just above the horizon of those in the last-mentioned quarries, are exposed. The northernmost quarry affords the best section, given as follows in descending sequence:—

	Ft.	In.
(1.) Grey sandy soil and reddish sand, the latter in pipes in (2) - - - - from nothing to	2	0
(2.) Unworn fragments of limestone scattered through green-grey loam, which is the upper part of (3) from 2 ft. to	3	0
(3.) Shaly drab and green-gray loam, fossiliferous, resting unevenly on (4) - - from 3 ft. to	8	0
(4.) Fine, compact, septarian, limestone mass, with crystalline matter and numerous corals. As this bed appears to be a coral growth its persistence and thickness is doubtful. It is exposed to the bottom of the quarry - - - from 3 ft. 6 in. to	5	0

In bed (3) *Gervillia* and numerous specimens of *Trigonia hemisphærica*, Lyc., were obtained. Bed (4) furnished the following fossils:—

Isastræa Richardsoni, *Ed. & H.*
Latimæandra Flemingii, *Ed. & H.*
Thamnastrea defranciana ? *Mich.*
Serpula socialis, *Goldf.*
Rhynchonella (young).
,, subangulata, ? *Dav.*
,, spinosa, *Schl.* (var. Crossi, *Walker*).
Astarte interlineata, *Lyc.*
Lithodomus, small ornamented, sp.
,, small smooth, sp.
Ostrea gregaria, *Sow.*
Amberleya.

Between Bracken Hill and Broughton, at about a mile south of the latter, rubbly nodular grey limestones belonging to the uppermost part of the Kirton Beds (probably the same as those visible near Scawby Brook on the west of Brigg) are exposed to a depth of from 5 to 8 feet in a

quarry. The limestones are very irregular, being in places separated by thin impersistent drab loamy partings; they are very fossiliferous. *Ostrea gregaria* appears to be the most abundant form, but *Lima bellula* and *Modiola* are also very common. The beds undulate slightly, but are, however, on the whole, almost horizontal.

Pecten lens was obtained at Springfield Cover, south-east of Broughton.

Near Broughton on the west, in a small exposure of rubbly Kirton Beds in a field in Broughton Woods, *Terebratula maxillata*, Sow., was obtained.

Broughton Woods, famed for the abundant growth of lilies of the valley* which carpet them late in spring, are situated on the west side of the Roman Road, between Scawby Wood and Gokewell. The soil is almost wholly Sand, but so irregular in thickness that the tree roots have in many places penetrated it and clamped themselves firmly in Kirton limestones, whilst in some parts of the woods the Sand has been whirled up into dunes. In the Autumn of 1881 many trees were blown down in these woods by a succession of severe storms; after these gales small patches of rock were exposed here and there, where the Sand was shallow, under fallen trees, sometimes with fragments of a bed of limestone clamped by their roots.

Grey limestones are exposed in pits on either side of the road to Bottesford at about a quarter of a mile west of the Roman Road, and in a pit by the avenue at about a quarter of a mile further north.

Lower beds in the Kirton Series are exposed south of the road to Bottesford; on the north and south of the farm on the Map, near the south margin of Broughton Woods; and just above the Basement Beds, in a quarry by the road showing oolitic limestones. Partially oolitic limestone is shown to a depth of about 3 feet 4 inches, not far from the Broughton entrance to the Woods.

Between Lincoln Hill, Scawby, and Sturton, the surface fragments afford evidence of dull grey semi-oolitic limestones, with large irregular oolitic grains in places; but they lack the distinctive characters of the Hibaldstow Beds and apparently belong to the upper part of the Kirton Series.

West of Brigg, between the words Scawby Brook, on the Map, and the high road west of them, irregular, brashy, argillaceous, grey limestones, containing numerous fossils, are exposed in a hedge section.

Similar limestones are shown in a shallow pit near an old wooden windmill, which is apparently situated upon the basement beds of the Hibaldstow Series.

These exposures appear, therefore, to represent the upper part of the Kirton Beds.

From the hedge-section the following fossils were obtained:—

Isastræa Conybeari, *M. Edw.*
Lima (cast).
Ostrea gregaria, *Sow.*

By the road from Scawby to Messingham limestones in the Kirton Beds have been quarried between the Roman Road and Scawby, and from small stone pits near Moor Farm. The very irregular outlier of Hibaldstow Beds shown on the Map at Scawby would appear to rest directly on a clay stratum, forming the top of the Kirton Beds about here; as clay has been dug out, on the western margin of the outlier toward Moor Farm, to clay the fields, which are covered with Blown Sand. Near the Roman Road, on either side, west of Scawby Vicarage, there are shallow pits showing brown and grey clay, and loam.

* Mentioned by De la Pryme. Diary of Abraham de la Pryme, the Yorkshire Antiquary (published for the Surtees Society), p. 137.

On the north side of the road east of Broughton, and about 30 chains from the village, a quarry affords the following section, given from the surface downwards :—

	Ft.	In.	Ft.	In.
Brown Sand soil	1	0		
Rubble of grey nodular limestone fragments	2	0 to	4	0
Brownish and drab shaly loam passing into shaly argillaceous limestone at about 6 inches from its base	2	0 to	3	0
Very hard, even-bedded, grey limestone, containing small *Terebratulæ*	1	0		
Light brown loamy clay, exposed for	1	0		

Near Wressle Houses on the north the upper part of the Kirton Beds is exposed in two quarries on either side of the turning to Broughton. The quarry on the south side gives the following section downward from the surface :—

	Ft.	In.
Brown Sand soil in pipes, giving place to a foot of old river gravel in the eastern part of the quarry.		
Rubble of broken grey limestone - 2 ft. to	3	0
Loamy clay with nodular limestone fragments	1	0
Loamy clay passing into shaly limestone at its base	1	0
Hard grey limestone	1	3
Loamy clay, with a line of race - 10 in. to	1	0
Hard, even, grey limestone	1	0
Pale drab loamy clay	2	0
Hard bluish-grey limestones, weathering light grey, exposed to the floor of the quarry	4	0

In the western part of the quarry the beds appear to be horizontal, but in the eastern part an apparent dip, E. 15 N., at 3°, was obtained. The beds are fossiliferous.

A similar easterly dip of 3° was observed in the adjacent quarry on the north.

The quarry on the north side of the turning to Broughton gives the following descending sequence :—

	Ft.	In.
Dark brown Sand soil	2	0
Rubbly Oolite limestone, the base of the Hibaldstow Beds	4	0
*Three even beds of grey limestone	3	3
Pale drab loam	1	6
Grey limestone	1	3 to 6 in.
Pale brownish, decomposed, shaly limestone	1	0
Hard, even-bedded, dark bluish-grey limestone, weathering light grey	1	0
Drab and dark grey loamy clay, passing into earthy limestone	2	6
Hard bluish-grey limestones, weathering to a pale drab colour	4	0

The beds below the asterisk (*) are the prolongation of those exposed in the adjacent quarry on the south, in which the beds above it are not represented.

Montlivaltia was obtained in these quarries.

Between Broughton and Far Wood, about 12 chains north of Barrow Hill, the Kirton Beds are exposed in a quarry belonging to Mr. Hett of Brigg. The section in descending order is as follows :—

	Ft.	In.
Sand soil	1	0
Rubble of broken fragments of grey limestone, possibly in part a superficial gravel	2	0
Pale drab loamy clay, with race, and argillaceous limestone at its base	4	0
Rather even-bedded limestone, weathering to pale greyish-brown	1	0
Hard bluish limestone	2	0
Brown shaly loam and clay	1	0
Dark grey shaly clay and loam	1	0
Grey limestones to the bottom of the quarry	1	9

The beds dip E. 10 S., at from 2° to 3°, but in the east side of the quarry a dip of 7° was noticed. The limestones are fossiliferous. *Lucina bellona*, D'Orb., was obtained. They appear to be a continuation of those in the quarries near Wressle Houses, in which case the 4-foot bed of drab loam would correspond to the upper beds of loam, from 18 inches to 2 feet thick, in the other quarries.

In the south-west corner of Rowland Plantation, between the roads to Appleby and Broughton Carr Side, shallow excavations showed the following beds under a surface rubble of limestone fragments :—

	Ft.	In.
Tough, grey, even-jointed limestone, quarrying out in somewhat irregular shaly pieces	1	2
Drab shaly loam	1	10
Hard, even-bedded, bluish-grey limestone	1	7

The dip appears to be N. 30 E. at 5°.

East of the above, on the south side of the road, the upper stratum of the Kirton Beds, a grey limestone, is visible at the bottom of old quarries in the Hibaldstow Beds, the dip appears to be in a north-easterly direction.

On the south of the Barnetby and Doncaster Line, near Low Santon Farm on the east, the upper part of the Kirton Beds is exposed under 5 feet of the shaly Oolites (Hibaldstow Beds) ; the top bed, a nodular argillaceous limestone, 2 feet thick, rests upon 8 feet of pale grey argillaceous limestones in which pieces of wood were obtained ; the beds dip in a north-easterly direction.

Between Winterton and Roxby the lower part of the Kirton Beds is either somewhat abnormal in character, being a development of the brashy material above and just below the Hydraulic Limestone near Cleatham, and of the speckled bed upon the Hydraulic Limestone near Raventhorpe ; or, through undulations in dip, these varieties are kept at the surface and present an appearance of development. That they should be mapped rather as the base of the Kirton Beds than as a part of the Basement Beds seems evident from the section by the lane on either side of the Railway Bridge at Low Santon (a Farm three-quarters of a mile west of Appleby Station), where, as far as the tumbled character of the section and an abnormally high dip of from 10° to 15° permits observation, the following section has been obtained—the beds are given in descending order :—

	Ft.	In.
Rather compact grey limestones with small fossils.		
Drab and brown sandy or loamy shale, partly consolidated, with grey clayey shale ; in the upper and lower parts beds of the Raventhorpe type occur, becoming in places very oolitic, and containing numerous small fossils at the base	about 9	0

	Ft.	In.
Rubbly and broken, tough pale brown and grey, irregular oolitic limestones, stained by ferruginous infiltration in places - - - - 5 ft. to	6	0

Hydraulic Limestone.
Impure (? arenaceous) broken limestone.
Lower Estuarine clays.

At rather more than half a mile west from Appleby Station *Myacites (Homomya) Vezelayi* D'Arch, and *Gresslya abducta*, Phil., were obtained.

Mr. Strangways supplies the following notes on the Kirton Beds of the Appleby and Winterton district:—

The Kirton Beds comprise the greater part of the Lincolnshire Oolite, and about Appleby cover a larger surface than the rest of the Lower Oolite divisions put together; they consist for the most part of siliceous earthy limestones, which become purer as we ascend in the series. The lower part of these beds is seen in the cutting at Santon, the upper beds are exposed under the Hibaldstow Beds in the quarry close by; from here the outcrop extends in a westerly direction along the ridge formed by Santon and Risby Warrens.

At Sawcliff the beds are thrown up by a fault and form a great spread, extending from the cliff edge east to Appleby and north to Winterton. In this area the limestone is exposed at many places and has been quarried and burnt for lime; the lower beds of the series, however, are somewhat abnormal in character.

North of Winterton the boundaries of the Kirton Beds become more obscure, and it is a matter of some difficulty to decide how much should be included within them. A large part of the rock when met with beneath the surface in shafts, boreholes, &c. has usually a dark shaly appearance, and this is probably the reason why, in the shafts and boreholes at Appleby, and also on the north side of the Humber, a considerable part of the section which must include this rock is called "bind."

These beds when burnt make good agricultural lime.

C. F. S.

HIBALDSTOW BEDS.

Along the road to Waddingham, eastward from the Roman Road, the more indefinite types of Lincolnshire Limestone noticeable in the north part of Sheet 83, give place to the more definite characters which led to the separation of Hibaldstow and Kirton Beds in Sheet 86. The surface fragments on the south side of the road prove the subjacent rock to be grey limestone without pronounced oolite structure. On the north side of the road, near the turning to Grange, buff, white weathering, oolitic (freestone) rock is exposed in a stone pit to a depth of 5 feet, and further proved by soil and surface fragments to be typical Hibaldstow Beds.

The lower part of the Hibaldstow Beds between Grayingham Warren Farm and Waddingham is of a similar type to that met with in the northern part of Sheet 83 on the same horizon, namely, cream-coloured and buff limestone with isolated oolitic grains; but this variety speedily gives place to the typical oolitic rock. The nature of these changes may be gleaned from the following notes:—

A shallow quarry, rather more than a quarter of a mile south-south-east of Grange Farm, west of Waddingham, shows pale bluish-grey, fossiliferous limestone, containing numerous corals, and breaking into irregular fragments. Grey limestones are also exposed at Grange Farm. These beds

resemble the upper limestones of the Kirton Beds, between Grayingham Warren and Wedge Wood.

A small exposure of oolitic rock is met with at the foot of the Great Oolite escarpment, at about a quarter of a mile from the margin of Sheet 86.

Near the margin of the Map, south-south-east of Grayingham Warren Farm, stone has been quarried in many places in a plantation; the pits are overgrown with one exception (near a house), which presents the following section:—

> Irregularly fissile, cream-coloured limestones with oolitic grains irregularly dispersed throughout, (of a brick red colour, apparently through burning, in places) for 2 feet 6 inches from the surface, upon cream-coloured and pale buff limestone, as above, but more massive, and not fissile, 2 feet 6 inches.

The underlying bed appears to be pale drab loam. The limestones are taken as the base of the Hibaldstow Beds; they contain numerous fossils, which, however, are specifically indeterminable. The following forms were found:—

Acrosalenia.	Lima.
Astarte (?).	Myacites.
Isocardia.	Nerinæa.

A well was sunk at the house by the plantation in which the above quarries are situated by Mr. Nicholson of Willoughton Grange; it was carried to a depth of about 24 feet in limestone.

From the above notes it would appear that the Hibaldstow Beds lose their intensely oolitic character in the lower part near Grayingham Warren and that their upper beds pass into, or are horizontally replaced by grey limestones in the same district. These changes are more fully treated of in the Memoir on Sheet 83.*

South of Hibaldstow, near Hibaldstow Mill, the Hibaldstow Beds are exposed in a quarry to a depth of from 15 to 20 feet; they consist of pale buff and cream-coloured Oolite, in rather thin broken beds, often containing large irregular granules; one bed either shows false bedding, or the effect is produced by irregular jointing. The beds appear to be horizontal in one part of the quarry, and in another to dip to the east at from 1° to 2°.

Traces of an abandoned quarry are manifest, north of the above, on the south-west side of Hibaldstow.

The surface *débris* of an old pit, on the west side of the high road between Hibaldstow Lodge and Redbourne, exhibits fragments of Oolite with irregular granules, betraying no trace of organisms and occasionally as large as small pebbles.

A disused quarry on the north of Redbourne, opposite the turning to Redbourne River Head, furnishes no exposure.

West of Redbourne the yellowish and cream-coloured Oolites of the Hibaldstow Beds are visible in shallow pits by the Roman Road, at about a mile south of the Railway; and in a small quarry near the Roman Road, by the path to Redbourne, on the Map, about a quarter of a mile further south.

Near the letter *n* in the words Island Pond, south-west of Redbourne, the lower part of the Hibaldstow Beds is exposed, to a depth of about 8 feet in a quarry.

At the cross-roads, east of Kirton and south-west of Redbourne, a shallow pit exposed beds of cream-coloured Oolite.

By the road to Kirton, at about 30 chains west of the cross-roads, a disused stone pit affords evidence of grey limestone, partly oolitic, which appears to belong to the basement beds of the Hibaldstow division.

* The Geology of the Country around Lincoln, *Mem. Geol. Sur.*, p. 44. 1888.

South of the cross-roads and east of the Roman Road, Hibaldstow Beds are exposed in a small pit by the road to Redbourne, on the south of the stream; and, in a larger pit, on the north of the stream, where beds of shaly Oolite are visible to a depth of 8 feet.

At a mile and a quarter south of Redbourne, Hibaldstow Beds are to be seen in pits by the road to Waddingham, and in a quarry on the south side of the valley, at about 10 chains west of the road; the beds in this quarry are apparently on the same horizon as those on the road to Kirton, west of the cross-roads, and, like them, partially oolitic, compact, grey limestones, in which *Lucina Bellona*, D'Orb., and *Trigonia hemisphærica*, Lyc, var., *gregaria*, and *Rhynchonella spinosa? Schl.* were obtained.

In the drain on the north of Traffords Cover, near Nowstead Old Causeway, thin, rubbly-bedded, yellowish Oolite, containing fair-sized irregular granules, is exposed. Oolitic beds are also visible in a small pit at the west end of Traffords Cover, where they exhibit a gentle anticlinal.

Oolite has been quarried near Hibaldstow on the north, and not far from Sturton on the south. East of Scawby Station the beds, to judge by surface fragments, appear to be much less oolitic than is usual in the Hibaldstow division; but there is no evidence of their being on a lower horizon.

The shallow cuttings, near Scawby, exhibit rubbly Hibaldstow Oolite. Beds of Oolite are exposed in the road-cutting where the Railway Bridge crosses it, south-west of Scawby Station, also in a quarry between the Railway Bridge and the Roman Road. On the east side of the Roman Road, opposite the path-road toward Manton, horizontal beds of buff and cream-coloured Oolite are visible in a quarry. Oolites are also evidenced near the path-road south of Stainewell.

One of the largest outliers of the Hibaldstow Beds is met with north of Kirton Railway Tunnel, between Cleatham and Church Hill: the beds are exposed to a depth of 8 feet in a quarry at the cross-roads to Cleatham (path road) and Hibaldstow Mill, they consist of white Oolite limestones and seem to dip at an angle of 1°, E. 15° N. The rock contains Corals and *Trigonia*.

The Hibaldstow Beds of the Scawby outlier are exposed in a shallow pit, on the south side of the stream, near the letter *b* in the words Scaw*b*y Hall.

In the year 1881 the foundations of a new house, near the high road west of Brigg, by the turning to Broughton and Wressle Houses, exposed brownish, rather shaly, Oolite to a depth of 8 feet. Beds of Oolite are also visible in the ditch at Silversides; in small pits on the south and east of Castlethorpe; by the turning to Castlethorpe Bridge; near the eastern termination of the outlier of Hibaldstow Beds south of Spring Field Cover.

In the quarry at Wressle Houses, on the north side of the turning to Broughton, the lowest part of the Hibaldstow Beds is represented by rubbly Oolite, 4 feet thick.

The Blown Sand boundaries between East Wood and Far Wood give the junction between Hibaldstow and Kirton Beds a more intricate appearance than it would otherwise exhibit on the Map.

At the north-east end of Far Wood the Oolite is exposed in a quarry. The beds are of a buff colour, the oolitic grains small; they have been quarried out in tolerably large slabs with irregular surfaces, and are visible to a depth of 5 feet.

That these beds belong to the base of the Hibaldstow division is proved by two adjacent quarries, in which the bottom rock consists of a thick irregular bed of grey (weathering pale brownish) limestone, directly overlain by the Oolite beds forming the sides of the excavations; this bottom rock is the top of the Kirton Beds.

Mr. Strangways continues the description of this division in the northern part of the area as follows:—

The Hibaldstow Beds consist of white very oolitic limestone, which is much purer and softer than that of the Kirton Beds below. A peculiar feature in the structure of the rock is that the

oolitic grains are often aggregated together into small lumps about the size of a bean, which give it, at first sight, almost the appearance of a conglomerate.

The division between these beds and those of the Kirton Series is not always very clear, although they usually make a small feature where they begin to come on.

In Rowland Plantation this part of the limestone is generally hidden by superficial beds of Sand, so that the rock is not well exposed; it has, however, been quarried in former times at a few places along the side of the main road, but these are now much overgrown and obscure.

In an old quarry by the road to Santon the lower part of this series is just exposed, forming a rubbly brashy Oolite, which is frequently decomposed into sand: the Hibaldstow Beds about here appear to be very thin, but perhaps the increased dip may in great measure account for the narrowness of the outcrop, or, what is more probable, the limestone may have been denuded before the deposition of the Great Oolite Clay above, as there appear to me to be indications of an unconformity between the two in this neighbourhood.

To the north of the railroad the rock makes a larger spread and is exposed in an old quarry in Mare Walk Plantation, in the beck near Appleby Mill and in several quarries and other places on Risby Warren. To the north of this the beds are thrown up by an east and west fault, so that we do not get this portion of the series except in the low ground to the east of Appleby; there are no good sections about here till we come to Mickle Holme, between which and Walks House the limestone has been quarried at several places. At a new farm-house at the latter place there is a well in which it is said 9 yards of rock was penetrated, but as no account was kept of the character of the rock it is impossible to say how much of this belongs to the Hibaldstow Beds, and how much to those below. The same difficulty also arises with reference to the borings about Appleby. Five of these, that is, those between Haverholme Plantation and the two shafts inclusive, must have passed through these beds, but there is no means of estimating how much of the limestone belongs to each group.

Between here and Winterton this limestone is again hidden by Sands, Boulder Clay, &c., but to the north of the town the beds rise to a higher level and are better seen, being exposed to the west of the Drift as far as the cross roads, rather more than a mile north of Winterton; beyond this the beds are entirely concealed by superficial deposits and are not again seen this side of the Humber.

In a quarry about half a mile north of Winterton the limestone is in larger blocks and seems more massive than elsewhere, but this may arise in great measure from its being more recently worked than the other quarries in the neighbourhood; the rock has a habit of breaking up very much and crumbling to pieces after exposure to the atmosphere, which usually gives it a very brashy appearance.

C. F. S.

CHAPTER IX.

LOWER OOLITES—*continued.*

Great Oolite Series.

The Great Oolite Series embraces four members, as shown in the following table:—

- **Great Oolite Series.**
  - Cornbrash. Thin, irregularly jointed, fossiliferous limestone.
  - Great Oolite Clay. Dark grey and greenish clay, *Ostrea* near top.
  - Great Oolite Limestone. Thin limestones, often brashy.
  - Upper Estuarine Series — Dark grey and greenish clay irregularly associated with sand.

In Sheet 83 each of these divisions can be studied from any point of view desired, but in Sheet 86 they present very much fewer facilities for observation. South of Hibaldstow, although the continuity of the features of the divisions is broken by tracts of Gravel, and Alluvium, we have sufficient proof of the persistence and behaviour of each; but from Hibaldstow northward to the Barnetby and Doncaster Line the Alluvium of the Ancholme conceals the whole Series, except near Brigg, where there is a small inlier (apparently, of Great Oolite Clay), and near Broughton Carr Side, where Clay with *Ostrea* is exposed in a Sand tract on the flanks of the Alluvium.

The Cornbrash is well shown near Thornholme Priory and Appleby Mill; it is, however, separated in this district by Clay alone from the Lincolnshire Limestone. The Clay is about the same thickness as the Great Oolite Clay, which it resembles in character. We are therefore obliged to conclude that the Great Oolite Limestone disappears altogether north of Brigg, and that the Great Oolite and Upper Estuarine Clays are brought together, and, being indistinguishable, constitute one group; or that the Upper Estuarine Clay also thins out northward. The alternative is mentioned by Mr. Strangways in his notes on the Hibaldstow Beds, (*vide ante*, p. 79), but I am indisposed to admit that the absence of the Great Oolite Limestone and Upper Estuarine Clay is due to the uncomformable overlap of the Great Oolite Clay upon the Lincolnshire Limestone, not being in a position to prove that the Upper Estuarine Series is really unrepresented in this district, and not regarding the disappearance of the thin series of brashy Great Oolite Limestones as evidence of unconformity.

It should be mentioned that it is possible to put such a construction upon the record of the bore hole made on the south side of Bridge Street, Brigg, by Mr. Joseph Parker, 1864–5 (at a spot 70 yards west of the River Ancholme), as to give a considerable thickness to the Great Oolite Series, and to make an Upper Estuarine Series composed as follows:—

	Ft.	In.	Ft.	In.
Grey shale	2	10		
Sandy shale	10	5	24	2
Sand	10	11		

This seems natural, and in accordance with the character of the beds as described above; but it entails the existence of Great Oolite Limestone under Brigg, as the overlying beds consist of—

	Ft.	In.	Ft.	In.
Sandstone rock	0	9		
Grey shale	1	6		
Hard rock, or Boulder	0	6		
Grey shale	0	11	11	7
Rock	1	1		
Unformed rock	6	10		

Over this we have blue shale, 24 feet 4 inches, which would be the Great Oolite Clay. If this be reliable the attenuation of the Upper Estuarine Series and dying-out of the Great Oolite Limestone must take place between Brigg and Appleby Station. South of Hibaldstow the Great Oolite divisions exhibit their usual features; the Cornbrash occupies a bed platform or dip-slope at the foot of the Kellaways escarpment; the Great Oolite Clay occupies the steep slope, constituting the Cornbrash escarpment: the Great Oolite Limestone rises from the foot of the Cornbrash escarpment westward to its outcrop, whence the ground falls in a steep escarpment-slope occupied by the Upper Estuarine Series.

UPPER ESTUARINE SERIES.

The Upper Estuarine clays and sands are evidenced on the slopes below the outcrop of Great Oolite Limestone, near Waddingham, and further north on the western slopes of the less pronounced features nearly as far as Hibaldstow.

Near Waddingham, on the west, blue clay and loam is shown in the ditch by the road to Grayingham, under the Great Oolite Limestone. The following fossils were obtained:—

Rhynchonella concinna (?), *Sow.*
Modiola imbricata, *Sow.*
Monodonta.
Ostrea Sowerbyi, *Lyc. and Mor.* var.

North of Waddingham a rather abrupt change from stone to clay and sand affords indication of a faulted strip of Upper Estuarine Beds.

In the ditch by the road to Redbourne, near Waddingham, the Great Oolite Limestone seems to pass into the Upper Estuarine Series, by clayey interstratifications. On the west of the road the upper part of the Upper Estuarine beds is blue clay, exposed in a pit; no fossils were obtained from it. On the east of the road the Upper Estuarine Series seems to be largely composed of white and buff sand.

Between Priestland Cover and Pyewipe Hall the relations of the Upper Estuarine beds and Great Oolite Limestone are not clear; the former appears to be for the most part sandy and loamy, but consist of clay in the upper part. The junction is visible between the words Pyewipe Hall on the Map.

Clay with *Ostrea* is shown beneath the Great Oolite Limestone in the drain north of the words Beanland Cover on the Map.

The eastern part of Redbourne Park is very sandy along the slope upon which the Upper Estuarine beds should crop out, and as white sand was turned out from a well nearly opposite the entrance to the Park (at half a mile south-west from Redbourne River Head) we may conclude that the Upper Estuarine Series is chiefly represented by sand.

Upper Estuarine clay with *Ostrea* is shown in Clay Dyke, but, as it is bounded by Drift on the west, the lower portion of the series is not exposed. It is very doubtful whether the sand strip bounding the Great Oolite Limestone west of Redbourne River Head is not part of the Upper Estuarine Series.

The road between Hibaldstow Mill and Low Bank exposes the upper part of the Upper Estuarine Series just under the Great Oolite Limestone, for about a chain in a shallow ditch. The Upper Estuarine Series consists of grey clay with sand and grey loam; it is overlain by a red-brown superficial clay on the west.

By the road between Low Bank and Hibaldstow, near the former, in a ditch, rubbly shale and dark grey clay, greenish in places, apparently associated with light-coloured sand, is exposed under shaly Great Oolite Limestone. This is the most northerly exposure of the Upper Estuarine Series we know of, there being no evidence to prove that it is continuous as the lower part of the Clay which, from Appleby Station to the Humber, and possibly from Brigg northward, separates the Cornbrash from the Lincolnshire Limestone.

GREAT OOLITE LIMESTONE.

The escarpment feature made by the great Oolite Limestone in Sheet 83 continues northward to Waddingham; on the north of Waddingham, probably owing to a change in the strike, and to small faults, the limestone feature is deflected from west to east, resuming the northerly trend at a point due north of Waddingham Church, from whence to Hibaldstow it is broken up into low hill patches surrounded by superficial deposits on flattish ground.

The Great Oolite Limestone, in Sheet 86, is generally composed of broken shaly limestone in beds of unequal hardness, much resembling Cornbrash on weathered surfaces, in places, but unlike it in texture, being either a somewhat arenaceous, or a hard, dark grey, siliceous limestone.

Near Waddingham, by the road to Grayingham, grey limestone containing *Pentacrinites* is exposed; it is interstratified with rubbly or brashy material, and below it the clays of the Upper Estuarine Series are shown. The relation of the Limestone to the Great Oolite Clay south of Waddingham is not visible, owing to the gravelly deposits on the flat south of Old Mill.

The lower beds of the Great Oolite Limestone north of Waddingham seem to have occasional clayey interstratifications, amounting in places to a passage into the underlying Estuarine Beds. By the road from Waddingham to Redbourne the descending section appears to be:—

	Ft.	In.
Brashy stone, probably with clayey seams -	3 ft. to 4	0
Clay - - - - - -	3	0
Brashy stone - - - -	3	0
Clay (Upper Estuarine) - - - -	8 ft. to 10	0

From the ditch section by the road to Redbourne, above mentioned the following fossils were obtained:—

Rhynchonella concinna, *Sow.*
Myacites calceiformis, *Phil.*
Trigonia undulata, *From.*

South-east of Priestland Cover brashy Great Oolite Limestones, under light brownish loam with fragments of *Ostrea*, are exposed in the bottoms of drains.

In a drain south of the letters *land* in the words Priest*land* Cover on the Map from 4 to 5 feet of Great Oolite Limestone is exposed, consisting of grey siliceous limestone, weathering light brown, in part very rubbly and irregular, splitting into shaly fragments, in part tolerably even; a thin band of light brown loam and clay, with *Ostrea*, separates two of the brashy stone beds. The following fossils were obtained:—

Rhynchonella concinna, *Sow.*
Modiola imbricata (?), *Sow.*
Ostrea Sowerbyi, *L. & M.*, var.
Trigonia (fragment).

From the Great Oolite Limestone in a ditch section at about 30 chains north of Waddingham Church the following fossils were obtained:—

Rhynchonella concinna, *Sow.*
Pecten vagans, (?) *Sow.*
Pteroperna plana, *Lyc.*
Trigonia undulata, *From.*

At half a mile east-south-east from Pyewipe Hall shaly and hard limestones, much resembling Cornbrash in places, in external appearance, are exposed at a drain junction, and yielded the following fossils:—

Corbicella, sp.
Cypricardia ?
Modiola imbricata, *Sow.*
Ostrea Sowerbyi, *L. & M.*
Trigonia undulata, *From.*
,, costata, *Sow.*

In the drain north of the words Beanland Cover on the Map, about a foot of pale bluish-grey, arenaceous, brashy limestone, with numerous *Serpula* and *Ostrea*, is exposed; similar shaly rock is shown in a drain, east of Beanland Cover, communicating with the above.

By the road from Redbourne to Redbourne Hays, at the bend near Redbourne River Head, about 3 feet of shaly limestone, arenaceous in places, and intercalated with more rubbly materials containing *Ostrea*, afforded the following fossils:—

Rhynchonella concinna, *Sow.*
Terebratula.
Avicula echinata, *Sow.*
Trigonia.

South of this exposure and near a Farm-house on the west of it, hard fragments of shaly limestone with *Ostrea* have been ploughed up; the

surface indicates Great Oolite Limestone nearly as far south as the drain separating this patch from the smaller one of Beaulands Cover.

At about a quarter of a mile west of Redbourne River Head, in a ditch, beds of irregular shaly limestone containing *Modiola* are visible. The limestones are also exposed in Clay Dyke.

In all the above-mentioned places, with the doubtful exception of the patch immediately north of Waddingham, the junction of the Great Oolite Limestone with the overlying Clay is concealed by superficial deposits.

The Great Oolite Limestone is next at the surface in an irregular patch, forming a low hill feature traversed by the road from Low Bank to Hibaldstow Mill and extending in one spot to the outcrop of the Great Oolite Clay above. North of the road toward Hibaldstow Mill fragments of shaly limestone have been ploughed up, and in the ditch by the road rubbly, fossiliferous, stone brash was observed.

In the bottom of Low Bank Drain for a few chains north of the turning to Hibaldstow about a foot of grey shelly limestone is exposed. In its unweathered state the rock appears to be a hard bluish-grey, somewhat crystalline, limestone. The following fossils were obtained from it:—

Rhynchonella concinna, *Sow.*
Terebratula intermedia, *Sow.*
Lucina ?
Lima rigida, *Sow.*
Modiola imbricata, *Sow.*
Mytilus furcatus, *Goldf.*
Ostrea Sowerbyi, *Lyc. and Mor.*
Trigonia costata, *Sow.*
,, striata, *Sow.*
,, flecta, *Lyc. and Mor.*

By the road to Hibaldstow, near the above, shaly limestone, with numerous shells, is exposed, apparently resting on Upper Estuarine beds.

From Hibaldstow northward there is no surface indication of the extension of the Great Oolite Limestones, though, as we have seen, they may be represented by 11 feet 7 inches of rock and shale in the boring at Brigg.

GREAT OOLITE CLAY.

On the south margin of Sheet 86, between the Cornbrash (which is imperfectly exposed in a stream) on the east, and the dip slope of the Great Oolite Limestone on the west, the Great Oolite Clay is concealed by a flat gravel tract. On the north of Old Mill the Clay emerges from the gravel tract and forms an irregular patch, which appears to be cut off from the Great Oolite Limestones on the north by an intervening band of stiff glacial clay. This patch is concealed in places by Sand, which also masks its junction with the Cornbrash on the east, and with the Cornbrash outlier of Waddingham Church.

The Great Oolite Clay, which is characterised by an abundance of *Ostrea* in its upper portion, is visible in ponds, on the west of the houses north, of Waddingham Church and north of the letter *i* in the word Waddingham on the Map, and by soil, and in ditches both north and south of the letters *gh* in the word Waddi*ngh*am on the Map.

North of the above the Great Oolite Clay forms the surface in three long strips or patches, overlain by Cornbrash on the east; the superficial continuity of the Clay is broken by the gravel-flat west of Wootham Hill and by the Alluvium near Redbourne River Head. The patches thus separated may be called the Nabs Hill patch, the Atkinson's Cover strip, and the Gander Hill strip.

The letter N of the words Nabs Hill on the Map is on Great Oolite Clay with numerous *Ostrea;* a pit in it furnished *Ostrea Sowerbyi.* Further south the Clay is proved by soil, and is shown in a pit by the gravel flat on the west margin of the strip of Cornbrash.

At the foot of the Kellaways Rock escarpment, along the west boundary of Atkinson's Cover, the Cornbrash seems to be concealed by a strip of Boulder Clay and Sand. Great Oolite Clay is shown in drains under the Cornbrash, and clay soil with quantities of *Ostrea* is ploughed up.

On the south of Atkinson's Cover, at 30 chains from Wootham Hill House, in a direction N. 35° W., there is a farm, not shown on the Map, called Paradise.

In the drain west of the bend in the road to Wootham Hill, south of Paradise Farm, Great Oolite Clay is exposed, and also in a pond near the limits of its southerly extension on the south of the drain.

Great Oolite Clay is exposed in the roadside ditch west of Paradise Farm; it is ploughed up in the field on the north side of the road, and is exposed at its junction with the Cornbrash in two drains south of the path to the house by Atkinson's Cover on the Map.

In the ditch by the road to Redbourne Hays grey Clay was exposed; it appeared to be mixed with yellowish-brown ferruginous matter and whitish stuff, probably race. This exposure has been mapped as Great Oolite Clay.

North of the above, near the northern end of the Atkinson's Cover patch, stiff greenish and blue clay is exposed in a small pit. Greenish hues are often present in the Great Oolite Clay.

The Gander Hill patch forms the outcrop slope of the Cornbrash escarpment, running from Gander Hill Farm on the north to within 10 chains of the drain between Ryecroft Hill and Redbourne River Head on the south. Clay Dyke cuts through the Great Oolite Clay at its junction with the Cornbrash, but it is best exposed in the ditch by the road opposite the bridle road to Gander Hill Farm. Here the Clay is dark bluish-grey, greenish in places, and very fossiliferous at its junction with the Cornbrash, *Ostrea gregaria*, Sow., *O. Sowerbyi*, L. and M., and *Rhynchonella concinna*, Sow., being the most abundant forms. From its mode of occurrence on the slope below the Cornbrash, the Great Oolite Clay may be from 20 to 30 feet in thickness near Gander Hill.

Great Oolite Clay may rest upon the Limestones in Low Bank Drain, east of Hibaldstow, but the section is very obscure.

From Low Bank to Brigg the Great Oolite Clay is concealed by Alluvium. It is proved at Brigg; but from Brigg northwards it is concealed by Alluvium and Sand for a distance of nearly 3 miles. The site of the Brigg Borehole, already referred to, is about 25 chains north-north-east from the spot where Great Oolite Clay appears at the surface. The Clay would appear to be 24 feet 4 inches in the Boring and was encountered at 105 feet from the surface, which would require a dip of about 8°, unless there is a fault between the localities.

Between the west end of Brigg and the Railway on the south the ground rises almost imperceptibly along the east side of the canal, forming a low feature, merging into the surrounding Alluvium. Where this tract touches the Railway, dark bluish-grey shales have been got out at a Mill. In a ditch crossing the feature Clay, plentifully charged with broken fragments of *Ostrea*, is exposed.

The boundary of the Great Oolite Clay with the Lincolnshire Limestone probably passes from under the Alluvium, and is concealed by Sand on the south of Wressle Wood.

The Clay, with fragments of *Ostrea*, is exposed by a pond in the Sand area north of Broughton Common, near the letter B in the words Broughton Carr Side on the Map.

On the east of Thorneholme Priory green and blue Clay, with *Ostrea*, is visible.

Mr. Cross, in his Paper on North Lincolnshire, says:—

"Next above the Lincolnshire Limestone there exists a deep clay, perhaps 40 feet, of a bright green colour in parts, the representative doubtless of some member of the Great Oolite Series."

He gives the following list of fossils from this clay:—

Icthyodorulite (Hybodus ?).
Palate of fish.

Gervillia crassicosta, *Lyc. & Mor.*
Modiola ungulata, *Y. & B.*
Ostrea Sowerbyi, *Lyc. & Mor.*
,, subrugulosa, *Lyc. & Mor.*
Perna quadrata? *Phill.*
Trigonia flecta, *Lyc. & Mor.*
,, n. sp. (near to pullus).

Cornbrash forms the surface for about a quarter of a mile west from Appleby Station; its junction with the Great Oolite Clay is shown in a pit on the south side of the Railway.

The peculiarity of the country about Appleby Station is the large superficial extent covered by so thin a bed as the Cornbrash, and the very short distance in which the comparatively thick series of Lincolnshire Limestone is disposed of, from its outcrop at the base of the slope in which the Great Oolite Clay pit is situated to the Low Santon road-cutting. This anomaly seems to be due to the fact that whilst the beds from the Ancholme Level westward to the outcrop of the Great Oolite Clay conform to the contour of the ground, dipping slightly in some places and being horizontal in others, the Lincolnshire Limestone locally exhibits, for these rocks, a high dip.

CORNBRASH.

Notwithstanding its thin representation there is no member of the Oolites of Lincolnshire more persistent than the Cornbrash.

In Sheet 86 the position of its outcrop on the margin of, or within the boundaries of, the Ancholme Alluvium accounts for the partial character of its superficial exposures.

Furthermore, in the south of the Map, where alone we could expect to find evidence of its relation to the Kellaways Rock, the dip-slope of the Cornbrash, where it emerges from the foot of the Kellaways escarpment, south of Redbourne Hays, and south of Wootham Hill, is masked by Sand, and furnishes evidence of glacial action, by which the Cornbrash has no doubt been shorn in places from its dip-slope.

Three feet appears to be the normal thickness of the Cornbrash in Sheet 86; in lithological character it seems to be almost unvarying.

Its brown colour is due to weathering, the rock being very thin and exposed at or near the surface.

Prof. Judd's description in the Rutland Memoir (pp. 218, 219) is very applicable to it in Sheet 86:—

"When it has been weathered, it breaks up into flat masses of a light brown colour, each of which is usually coated with stalagmite; in this condition the appearance of the rock in section has been not inaptly compared to that of a loose stone wall or field-dyke."

Certain fossils are almost as distinctive of the Cornbrash as its lithological characters; *Avicula echinata*, Sow., is perhaps the most abundant species.

It should be mentioned that the Great Oolite Limestone bears so strong a resemblance to the Cornbrash in places, that it was

mistaken for it both on the north and south of Waddingham; the mistake was rectified on tracing the beds southward into Sheet 83.

This resemblance is fortunately very partial. In the road from Redbourne to Waddingham the uppermost bed, as also beds presumably on the same horizon exposed under the roots of fallen trees, at about half a mile north of Waddingham Church, were taken at first for Cornbrash; as they rested on clay about a foot thick it was thought that the Great Oolite Clay had thinned out.

Cornbrash is not exposed on the southern margin of Sheet 86, being concealed by sandy *débris* from the Kellaways Rock, and by the superficial gravel of the Waddingham valley; it is, however, visible in a stream bank at the road from Waddingham to Black Dyke, at three-quarters of a mile south-east from Waddingham Church. From this exposure the following fossils were obtained:—

Clypeus Plottii, *Klein.*
Holectypus depressus, *Leske.*
Rhynchonella, fragment.
Ostrea Sowerbyi, *L. & M.*
Astarte elegans, *Sow.*, fragment.
Isocardia rostrata ?, *Sow.*
Trigonia costata, *Sow.*
„ (small).

From this exposure northward, as in the case of the Great Oolite Clay, the Cornbrash occurs on the surface in patches separated by the gravels and alluvial soils of the Waddingham flat, on the north of Wootham Hill and east of Redbourne River Head.

Waddingham Church stands upon a small outlier of Cornbrash, masked more or less by Sand.

East of Waddingham the Cornbrash is concealed by Sand, which mantles over the slope of the Kellaways Rock feature; but its position can be ascertained here and there by a slight subsidiary feature. This feature becomes distinct at about half a mile north-east from Waddingham Church, the characteristic fragments of fossiliferous limestone being ploughed up and the underlying Great Oolite Clay exposed. The Cornbrash is overlain by blue Clay on the east, which may be either solid rock or Drift; if the former, its exposure is exceptional.

From Nabs Hill to Wootham Hill no evidence of Cornbrash is procurable; but on crossing the flat that separates Wootham Hill from the Atkinson's Cover patch, we encounter Cornbrash on Great Oolite Clay in a drain south of Paradise Farm (not on Map). From this drain to the road west of Paradise Farm the Cornbrash is probably concealed by superficial deposits, but in the field on the north of the road near Paradise Farm it has been ploughed up, and can be traced thence northward by soil and in ditches nearly as far as the road to Redbourne Hays. In this extension, although its relation to the Great Oolite Clay is very clear, the boundary of the Cornbrash at the foot of the low Kellaways escarpment is very obscure, as there is evidence here and there along the west side of Atkinson's Cover of superficial deposits, probably glacial.

In one spot on the margin of Atkinson's Cover the Cornbrash was proved, by the spud, to be very thin on Great Oolite Clay.

On the west of Atkinson's Cover the Cornbrash is exposed at its junction with the Great Oolite Clay in drains traversing its dip-slope from east to west, and, in one instance, from north to south. In one of these drains nearly 3 feet of Cornbrash was visible.

The following fossils were obtained:—

Waldheimia ornithocephala, *Sow.*
Astarte.
Myacites calceiformis, *Phil.*
„ decurtata, *Phil.*
Trigonia flecta, *L. & M.*
„ elongata, *Sow.*, var. angustata.

The Cornbrash of the Redbourne Hays and Atkinson's Cover district is very imperfectly exposed in the northern part of the patch; it is separated from the Gander Hill Cornbrash by Alluvium.

The Gander Hill Cornbrash extends from Gander Hill Farm on the north to within 10 chains of the drain between Redbourne River Head and Ryecroft Hill, on the south; it forms a low escarpment hill-crest, whence it declines gradually on a dip-slope to the Alluvium on the east.

The rock is exposed very near Gander Hill Farm on the south-east in a drain; it is also exposed in drains south of Gander Hill Farm, on its dip slope; but its best exposures are by the road to Hibaldstow at the bend south of Gander Hill and by Clay Dyke.

As exposed in the ditch by the road to Hibaldstow, the Cornbrash consists of 3 feet or so of grey limestone, weathering buff, and splitting in thick irregular shaly pieces, frequently coated by concretionary stalagmitic matter.

The following fossils were obtained by the Survey fossil collector from this ditch:—

Acrosalenia.
Holectypus depressus, *Leske.*
Rhynchonella obsoleta, *Sow.*
Terebratula intermedia, *Sow.*
Waldheimia obovata, *Sow.*
Ostrea (fragment).
Myacites decurtata, *Phil.*
Nerinæa.

In addition to the above, the following were obtained and identified by Mr. Etheridge:—

Strophodus magnus, *Ag.*
Avicula echinata, *Sow.*
Unicardium (? sp.).

The Cornbrash is shown resting on the Great Oolite Clay in this ditch, and also in Clay Dyke.

By Clay Dyke the following fossils were obtained from the Cornbrash:—

Avicula echinata, *Sow.*
Ceromya concentrica, *Sow.*
Myacites Vezelayi, *D'Arch.*
Pholadomya Phillipsi, *Mor.*

From Gander Hill to Thornholme Priory, a distance of more than six miles, the Cornbrash is concealed by the Ancholme Alluvium, and, perhaps, by Sands beyond Wressle Wood.

In the Brigg boring it appears to be mentioned as Limestone rock, 3 feet thick, encountered at 102 feet from the surface.

Mr. Cross* gives the following list of fossils obtained from the Cornbrash of the Appleby district:—

Ammonites macrocephalus, *Schl.*
,, Herveyi, *Sow.*
Chemnitzia scarburgensis ? (cast).
,, vittata, *Bean.*
Natica, sp. (cast).
Opis, n. sp.
Nucula variabilis, *Sow.*
Astarte minima, *Sow.*
Trigonia Moretoni, *Lyc. & Mor.*
,, flecta, *Lyc. & Mor.*
,, Rolandi, n. sp., *Lyc.*

* *Quart. Journ. Geol. Soc.*, vol. xxxi., p. 125.

Trigonia scarburgensis, *Lyc.*
Modiola imbricata, *Sow.*
,, Lonsdalei, *Lyc. & Mor.*
,, gibbosa ?, *Sow.*
,, Sowerbyi = plicata, *Sow.*
Goniomya V-scripta, *Sow.*
Myacites modica, *Bean.*
,, decurtata (var.), *Phil.*
,, sp.
,, sinistra, *Agass.*
,, calceiformis, *Phil.*
Lucina burtonensis ?, *Lyc.*
,, Lycetti = crassa, *Sow.*
Isocardia nitida, *Phil.*
,, sp.
Cypricardia, sp.
Corbis rotunda ? *Walton.*
Corbicella bathonica ? *Lyc. & Mor.*
Arca (rare).
Gresslya.
Pholadomya Murchisonæ, *Sow.*
,, acuticosta, *Sow.*
Cardium Stricklandi, *Lyc. & Mor.*
,, semicostatum, *Phil.*
,, cognatum ? *Phil.*
Lima rigidula, *Phil.*
,, duplicata, *Sow.*
Pecten lens, *Sow.*
,, rigidus, *Sow.*
,, articulatus, *Schl.*
,, inæquicostatus, *Phil.*
,, hemicostatus, *Phil.*
,, subfibrosus, *D'Orb.*
Perna obliqua, *Walton.*
Gervillia acuta, *Sow.*
,, ovata, *Sow.*
Avicula echinata, *Sow.*
Terebratula lagenalis, *Schl.*
Waldheimia obovata, *Sow.*
Rhynchonella concinna, *Sow.* (dwarf).
Serpula.
Echinus.

All the sections exposing Cornbrash near Appleby Station show the underlying Clay. *Ammonites macrocephalus* was obtained at rather more than a quarter of a mile from Appleby Station, by the road to Low Santon Farm, from the base of the Cornbrash, exposed on Great Oolite Clay in a pit.

The following notes on the Cornbrash of the Appleby district are by Mr. Strangways:—

In the neighbourhood of Appleby the Cornbrash is well exposed at several places. It consists of a thin rubbly limestone, very fossiliferous, breaking up into small flattish pieces, which are usually covered with a calcareous deposit.

The best sections of these beds are at Appleby Station and in a pit close by and also in an excavation on the road to Santon, at which latter place *Ammonites macrocephalus* was found: there is also a good section at Thornholme Priory, where the Cornbrash has been removed to get at the Clays below, at this place the commonest species are *Trigonia striata*, Sow. *T. Moretoni*, L. & M.; *Modiola imbricata*, Sow.; *M. gibbosa ?*, Sow.; *Avicula echinata*, Sow.; *Avicula braamburiensis.*, Sow.

With the exception of the outlier at Appleby Station, the outcrop of the Cornbrash follows the line of Sir Rowland Winn's Drain, being seen at three places, namely, just north of the railway; about a mile and a quarter north of this point; and again at Mickle Holme and Scotney Hill, north of which it passes beneath the Alluvium of the Ancholme valley, and is not again seen in the county, nor, in fact, until we come to the north side of the Yorkshire basin, a distance of about 46 miles.

The Cornbrash also probably outcrops near the farm at Winterton Holme, but was not seen there, the hill being entirely masked by Drift.

The Yorkshire Cornbrash may be of equivalent age, although it is not a settled point whether it is exactly contemporaneous with that of this county.

C. F. S.

CHAPTER X.

THE JUNCTION BETWEEN THE LOWER AND MIDDLE OOLITES.

The relation of the Cornbrash to the Middle Oolites above is very uncertain in Sheet 86.

From the Humber southward to Gander Hill, a distance of 12 miles, there is only one place where we could expect to obtain evidence of the nature of the junction, namely, on Winterton Holme, and here it is as effectually masked by Drift as it is by the Ancholme Alluvium on the north and south.

In the Brigg boring a bed of sandstone, 2 feet thick, was encountered at 82 feet from the surface; this certainly represents the Kellaways Rock: under it we have 18 feet of "Blue Shale," upon 3 feet of "Limestone rock," which we unhesitatingly regard as Cornbrash.

The meagre evidence we have, from Gander Hill southward, of this clay, or shale, between the Cornbrash and the Kellaways Rock may be gleaned from the following notes:—

Kellaways sand and rock is exposed at Gander Hill, so close to Cornbrash *in situ*, that there is no room for an intervening clay band of more than two feet in thickness: and, at the same time, there is nothing to justify the insertion of a fault to account for the absence of the "Blue Shale" of the Brigg boring.

Between Gander Hill and Redbourne Hays the junction beds between Cornbrash and Kellaways are concealed by Alluvium.

From Redbourne Hays southward the Kellaways makes a marked escarpment, the steep slope of which is in Atkinson's Cover. At the foot of the escarpment the Cornbrash is concealed by a clay, apparently of glacial origin, and the steep slope from top to base consists of sand, which is no doubt to a great extent rain-wash from the Kellaways Sands or Drift Sands overlying them.

This escarpment-slope above the Cornbrash, both here and from Wootham Hill and Nabs Hills southward, would represent a greater thickness of Kellaways beds than the 2 feet in the Brigg neighbourhood renders likely, even supposing a very rapid development southward; it seems therefore probable that the Kellaways is based by clay which is concealed by a thick mask of sand *débris* on the face of the escarpment.

By the road south of the letter *b* in the words Nabs Hills on the Map, bluish dicey Clay is shown, its presence at the foot of the escarpment being further proved by ponds: this Clay, if not of glacial or alluvial origin, would be the stratum intervening between the Cornbrash and Kellaways Beds.

South of the road from Waddingham to Black Dyke, at about three-quarters of a mile from Waddingham, a pit at the foot of the Kellaways escarpment afforded indications of dark grey Clay; the pit was grass-grown its sides exposed sand, probably a wash from above, but if *in situ*, as Cornbrash is visible in the adjacent stream on the west, the Clay can scarcely exceed 4 feet in thickness, and might not be more than 2 feet.

The above notes furnish all the materials at our disposal for ascertaining the nature of the junction beds between the Lower and Middle Oolites in this district. It only remains, therefore, to

refer to the districts on the north (Yorkshire) and on the south (Rutland) already described in the Memoirs of the Geological Survey, and to follow the classification best suited to the meagre array of evidence afforded in the area under description.

Mr. Strangways* describes the Cornbrash of Scarborough as "a grey rubbly ironshot limestone, partially oolitic and very fossiliferous," "not more than a few feet in thickness," overlain by "about 6 feet of finely laminated bluish-grey shale, containing *Avicula echinata*, &c. †; "the so-called" clays of the Cornbrash "which pass gradually up into the yellow argillaceous base of the Kellaways Rock."

Although in the Midland Counties we seek in vain for the counterpart of the Avicula Shales or Cornbrash Clay, and find the Kellaways Rock often so degenerate as not to be separable from the Oxford Clay, yet there is a homotaxeous stratum characterised by abundance of *Ostrea Marshii*, as mentioned by Prof. Judd.‡

In the section at Dogsthorpe, given by Judd, the Cornbrash is separated from sandy clay and sandy rock, by an overlying stratum, 7 feet thick, consisting of "hard blue 'dicey' clay with *Nucula nuda*, Phil., *Corbula*, sp., *Ammonites Herveyi*, Sow., &c." The lowest bed of this clay is crowded with *Rhynchonella*, and other fossils.

The Humber valley Alluvium, the glacial deposits of South Yorkshire, and the overlap of the Cretaceous Rocks in that area, entirely prevent any proof being obtainable of the continuity of the clay above the Cornbrash in Sheet 86, south of the Humber, with the Avicula Shales of the Scarborough district; and, although certainly homotaxeous, no fossils have been obtained in it, in Sheet 86, to warrant our including it in the Lower Oolites as Cornbrash Clay, as has been done in Yorkshire. On the other hand, although the evidence of a persistent clay stratum at the base of the Kellaways is hardly more conclusive in Sheet 83 (the adjacent Sheet on the south), and fossils have not been obtained, yet the continuity of the Kellaways Beds and Cornbrash with these formations in the Midland Counties is certain; so that the clayey base of the Kellaways, whether persistent or fitful in its occurrence, should be classified in the area under description with the Middle Oolites, as has been done in the Midland Counties. This view is strengthened by the fact that the Kellaways Rock does not constitute the base of the Oxford Clay in the Midland and more southerly districts. Where separated from the Kellaways, in Sheets 83 and 86, this clay stratum has therefore been included in the Middle Oolites and coloured as Oxford Clay on the Maps. Where, however, it has not been separated, as in the south part of Sheet 83, in Sheet 70, and further south, its absence is by no means to be inferred.

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* Mem. Geol. Survey; Geology of Scarborough, p. 10.
† *See* W. H. Hudleston, Proc. Geologists' Assoc., vol. iv., p. 362.
‡ Mem. Geol. Survey; Geology of Rutland, pp. 219 and 226.

CHAPTER XI.

MIDDLE OOLITES.

The Middle Oolites in Sheet 86 consist of clay, sandstone and sand. The former is the Oxford Clay, a stratum of dark bluish-grey clay, probably about 300 feet in thickness, resting upon a thin stratum of sandstone near Brigg, which develops further south into a series of sands irregularly consolidated into rock, and may attain to a thickness of 20 feet: these are the Kellaways Beds, as has been shown; they are, at any rate locally, separated from the Lower Oolites by a thin intervening bed of Oxford Clay or shale, described in the preceding Chapter.

Through the absence of the stone beds of Corallian age there is no lithological boundary between the Middle and Upper Oolites, the latter being represented by Kimeridge Clay indistinguishable from the underlying Oxford Clay, and only separable from it by the discovery of fossils in the Railway cuttings near Elsham and in pits in the district east of the Ancholme, south of Brigg.

KELLAWAYS ROCK AND SANDS.

The Kellaways Beds consist of an irregular association of yellowish and buff sands with brownish and buff sandstone, either variety locally predominating; as the sandstone is crowded with *Gryphæa bilobata* and *Belemnites*, whilst the sand is sparingly fossiliferous, the effect of infiltration where shelly matter prevailed amply explains the irregular consolidation of the sand.

From Redbourne Hays southward the Kellaways Rock forms a marked escarpment feature broken on the north of Wootham Hill and by the Waddingham valley (west of Brandy wharf), and although largely concealed by glacial Sands, more especially at its outcrop, the nature of the rock is well shown in ditch sections.

South of Brigg, Kellaways Rock is visible near Gorbet Bridge, in imperfect ditch exposures. On crossing the Alluvium from Sand Hill to Gander Hill, a sand pit in close proximity to an exposure of Cornbrash shows the very impersistent character of the Kellaways as a hard rock, a similar instance being furnished by a sand pit in Redbourne Hays Farmyard.

In the boring made by Mr. Joseph Parker in 1864–5, on the south side of Bridge Street, Brigg, at 70 yards west of the river Ancholme, the Kellaways Rock seems to be represented by a bed of sandstone, 2 feet in thickness, encountered under clay, at 82 feet from the surface. It is therefore difficult to account for the exposure of the upper beds of the Lincolnshire Limestone at Silversides, at half a mile to the west, without invoking a fault or a high dip.

The Kellaways Rock, if persistent, is effectually concealed by the Alluvium of the Ancholme and the Glacial Deposits bordering it between the Barnetby and Doncaster Railway and Brigg.

From the Barnetby and Doncaster Railway to the Humber the Kellaways horizon is buried beneath the Alluvium of the Ancholme except on Winterton Holme Hill, where it is concealed by Drift.

North of the Humber, although concealed by superficial deposits south of Brantingham, the Kellaways Beds come to the surface in the north part of Sheet 86, near South Cave.

The Kellaways escarpment bounds the gravel flat south of Old Mill on the east, and falls gently eastward merging into the Ancholme Alluvium; its continuity is broken by the connexion of the Waddingham gravel flats with the Ancholme Alluvium.

By the Black Dyke road, at a mile and a quarter from the Ancholme Canal, Kellaways Rock was exposed in a ditch to a depth of about 5 feet. At about half way between this exposure and the southern margin of Sheet 86 a roadside section displays sand and rubbly sandstone to a depth of 2 feet; the sandstone contains numerous *Belemnites* and *Gryphæa bilobata* in abundance, besides which *Gryphæa* with the markings of *Ceromya* (?) were obtained from it.

Kellaways Rock is also evidenced by Black Dyke road, at about a mile from the Ancholme. Oxford Clay is at the surface in Black Dyke, at the letter *B* of these words on the Map.

From Wootham Hill southward to the Waddingham valley the Kellaways makes a very distinct feature, but it is impossible to be certain of the extent of surface occupied by the Rock and Sand; for, as we have said, the consolidation of the sands into hard rock is most irregular, having nothing to do with stratigraphical position, and glacial or subaërial agencies at work upon its unconsolidated surface would no doubt produce deposits nearly indistinguishable from its natural soil. This is the case south of Wootham Hill, where, although there are several exposures of undoubted Kellaways Rock and Sand, the principal, and more especially the western, parts of the feature are covered by Sand in which occasional pieces of flint occur, but nothing like Kellaways Rock is found, although the Sand is indistinguishable from Kellaways Sand. This Sand masks the outcrop slope of Kellaways Rock, and in the southern part of the patch also entirely conceals the Cornbrash. At the letters *bs* in the words Nab*s* Hills on the Map Sand is exposed; it may be either Kellaways Sand partly slipped, Kellaways Sand blown, or a glacial Sand derived from the same source. On the north side of Waddingham Holme Farm buff and white sand is exposed in a ditch; respecting this the same uncertainty prevails.

In a drain on the border of the Alluvium, at about half way between Green Dyke and Black Dyke, south of an exposure of Oxford Clay, Kellaways Rock is visible.

Kellaways Rock is exposed in a ditch by a lane at some cottages about 30 chains south of Waddingham Holme.

Kellaways Rock is exposed in drains at a quarter of a mile north of Waddingham Holme.

At the drain junction south-east of Wootham Hill the Rock is exposed to a depth of from 3 to 5 feet. *Gryphæa dilatata* and *Belemnites* were obtained in it. At the northern termination of this patch, north and north-east of Wootham Hill, Kellaways Rock is visible.

The Redbourne Hays patch is separated from that of Wootham Hill by Alluvium; its southern margin presents the same difficulties as the patch south from Wootham Hill.

From the Alluvium northward to within a quarter of a mile of Redbourne Hays there is evidence of drift Sand with a patch of gravel, extending over the outcrop slope, and for some distance eastward down the dip slope, of the Kellaways Rock.

The general composition of the Kellaways is well exemplified by one of the drains in which it is exposed, between the words Atkinson's Cover and

Hays Wood, on the Map, here it consists of tough greyish brown sandstones, broken up in irregular pieces, and containing numerous specimens of *Gryphæa bilobata* and *Belemnites*; the rock gives place abruptly and irregularly to whitish and buff sand and sand-rock containing a few *Belemnites*.

The irregular association of sand and sandstone is also well shown in a drain along the alluvial boundary south of Hays Wood, and in cross drains from it, at about 25 and 30 chains from Hays Wood.

Near Redbourne Hays, the Kellaways Rock is exposed in a ditch under an irregular capping of clay which may be Oxford Clay but has been considered as glacial; as also in a drain at about 12 chains south of Redbourne Hays, and in a drain on the south side of Hays Wood.

In Redbourne Hays farmyard the Kellaways is exposed in a pit showing two small masses of sandstone with *Gryphæa bilobata*, in, and on, whitish and buff sand. The fragmentary sandstone is near the surface.

In a ditch on the south side of the broad drain, between Redbourne River Head and the Ancholme Canal, at about 30 chains from the latter, Kellaways Rock, irregularly associated with sand, is exposed.

From the broad drain at Ryecroft Hill the ground rises northward, forming a hill nearly half a mile in length; the soil consists of sand with pieces of flint. Clay Dyke intersects the hill, and whitish sand is exposed in it. It is quite possible that, in this instance, and also in the case of the sand hill from Newstead Priory to Sand Hill Farm, about a mile and a quarter further north, the Kellaways may be represented altogether by Sand, the flints being relics of Boulder Clay, or glacial gravel; but, there being no certain proof of this, the features in question have been treated as glacial Sand.

At Gander Hill, just south of the letter *G* on the Map, a small patch of Sand forms a mound, or knoll, on the border of the Alluvium. A pit in its summit exposes whitish, buff, yellowish, and brownish fine sand to a depth of from 1 to 3 feet. A fragment or piece of a bed of tough sandstone containing numerous *Belemnites*, 6 inches in thickness, is noticeable on the sand, under from 3 inches to a foot of brown sandy soil. Within 2 feet from the surface a few pieces of flint were obtained, they may have been washed in from the surface (*i.e.*, gradually subsided to their present positions). A Quartz pebble (apparently *in situ*) was also found in the sand. In the same field, at a few yards from the pit, a ditch 8 chains in length shows Boulder Clay for 3½ chains from the corner nearest to Gander Hill; the clay appears to be associated with sand. The rest of the ditch exposes Cornbrash much broken up near its junction with the Boulder Clay.

It is possible that the Sand in the pit mentioned above may be glacial, but we have on subsequent investigation regarded it as Kellaways, probably to a certain extent mixed with drift soil, and, either separated from the adjacent Cornbrash by a fault, or almost directly superimposed on it.

By the road from Cadney to Newstead Priory, at about 5 chains west of Black Bank, Kellaways Rock is visible in the drain.

Kellaways Rock is shown in a drain at about 12 chains east of Newstead Priory: between this and the foregoing observation, buff and reddish sand, probably Kellaways, is exposed in a ditch.

In Faraway Drain south of Gorbet Bridge, Kellaways Rock has been observed under the Oxford Clay.

In a ditch by the road to Newstead Priory, near Gorbet Bridge, from 2 to 3 feet of buff and yellowish, ferruginous sandstone and sand, the former containing *Gryphæa bilobata* and *Belemnites*, is exposed, apparently, on, and under, Clay.

Near the above, on the west of Gorbet Bridge, the Kellaways Rock makes a small mound feature, traversed by a shallow ditch in which its sand and sandstone is exposed.

By Faraway Drain, north of Gorbet Bridge, blue shales (Oxford Clay) have been cut through, Kellaways Rock apparently forming the bottom, and in some places the lower part of the sides of the drain. At a mile and a quarter south of Brigg, slightly ferruginous Kellaways sandstone

is shown by the drain; *Gryphæa bilobata*, Sow. and *Belemnites Owenii*, Pratt. were obtained from it.

At about 16 chains south of Kettleby Dyke in the sides of a drain, between Faraway Drain and the Ancholme Canal, there appears to be an undulating bed of Kellaways Rock. Fragments of rubbly sandstone, containing *Gryphæa bilobata* and *Belemnites*, were turned out of the drain.

Kellaways Rock is visible in the bottom of a ditch on the south side of Kettleby Dyke, near the letter K of the word Kettleby on the Map; *Avicula braamburiensis*, Phil. was obtained from it. At about 9 chains south of this the Rock is exposed in Faraway Drain.

Mr. Strangways continues the description in the north of the district as follows:—

From this point northwards to the Humber the Kellaways Rock is not exposed, being everywhere concealed by the Alluvium of the Ancholme, except at Winterton Holme, which projects far enough to the east to cross its outcrop; the beds here, however, are covered by Boulder Clay, so that no evidence of the Rock was obtained, and the outcrop shown on the Map is therefore hypothetical.

North of the Humber the Kellaways Rock appears again on the flanks of the hill, south-west of Elloughton,* but it is here also so often covered by superficial sands that it is difficult to distinguish one from the other; farther north, however, it rises above these superficial deposits and forms a good feature in the neigbourhood of South Cave, where it has been dug for sand and is sufficiently consolidated to be excavated into small cave-like recesses.

The Kellaways Rock was also met with in a trial shaft at Brantingham and in the cutting of the Hull and Barnsley Railway just beyond the limit of the Map, where there was a fine section.†

*OXFORD CLAY.

From Elsham Station southward, on the hill sides bounding the alluvial deposits of the Ancholme valley on the east, Oxford Clay frequently comes to the surface.

The junction between the Clay and Kellaways Rock is only visible in two or three places, on the west side of the Ancholme valley, south of Brigg, and the Oxford Clay is only exposed in two or three places, viz., between Waddingham Holme and Black Dyke; by Black Dyke; and on the east of Redbourne Hays.

From the Humber southward to Elsham Station the Oxford Clay is concealed by the Alluvium of the Ancholme Level, except on Winterton Holme Hill, where it is for the most part obscured by glacial deposits.

North of the Humber the Oxford Clay occupies a small tract near South Cave; south of Brantingham it is concealed by superficial deposits.

By Black Dyke the lower part of the Oxford Clay, consisting of bluish-grey and buff shaly clay, is exposed, at the letter *B* of the word *B*lack on the Map; *Posidonomya* and *Leda Phillipsii*, Mor., were obtained in it.

The Oxford Clay seems to be near the surface, not far from the southern margin of Sheet 86, on the south of Owersby Drain, at about half a mile from Gullham.

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* Kellaways rock (6 feet) was perhaps encountered in the well south of Elloughton (*see* p. 164).

† *Mem. Geol. Survey*, The Geology of the country between York & Hull, p. 23.

On the western margin of the Ancholme Alluvium, east of Redbourne Hays, bluish-grey clay with bits of flint forms the surface; it is either a Boulder Clay or the base of the Oxford Clay with relics of Drift. In either case it seems probable that the junction of the Kellaways Rock and Oxford Clay is not far from Redbourne Hays. At about 92 chains from Waddingham Church, in a direction E. 30° N., Oxford Clay is shown in a drain close to the Alluvium, and in another place Kellaways Rock is visible in the bottom of the drain.

At Holme Hill Oxford Clay appears at the surface; it is surrounded by Drift of irregular thickness.

Oxford Clay forms the slopes between Caistor Canal and Thornton Lodge, except at Winghall, where it is partially concealed by Drift, and between Winghall and South Wood, where it is frequently masked by sandy soils; north-west of Gullhan the Clay is concealed by low-lying Drifts.

In the drain between Caistor Canal and Winghall Ferry, Oxford Clay is exposed at one place, about 7 furlongs west of South Kelsey Church; *Gryphæa dilatata* was obtained in it, also a cast of the middle portion of an Ammonite (*? biplex*).

On the north side of Winghall farmyard dark grey clay, containing *Gryphæa dilatata*, forms the sides of a pond.

Between Ings House and Caistor Canal, in a drain at Decoy House, dark grey shaly Oxford Clay was exposed for a chain.

Blue shaly clay is said to have been got out below the farm buildings at nearly a mile and three-quarters from North Kelsey Church in a direction W. 16° S.

Blue clay is exposed in the Brickyard by the side of the Canal, about half a mile north of South Kelsey Church. The fossils obtained from it will be found in the next chapter, and the section is given by Mr. Jukes-Browne in the chapter on the Upper Oolites. The lower part of the pit appears to be in Oxford Clay.

From the Alluvium of North Kelsey Beck to Caistor Canal the slopes are formed of Oxford Clay, partially concealed by Sand at Ings House and north-west and south of it. In this tract (not extending as far east as North Kelsey) the following observations were made:—

At the head of the valley between Gadney and Kelsey New Mill, a pit shows dark grey shales under 5 feet of Drift.

At about a mile and a quarter W. 8° S. from North Kelsey Church, dark grey Clay was noticed in the ditch by the roadside in close juxtaposition to Drift sand. *Serpula tetragona*, Sow., a minute Gasteropod and *Cucullæa*, were obtained in the Clay.

Between the boundary of the Cadney Gravel and the Alluvium west of it no certain evidence of Oxford Clay at the surface was procurable, but it forms the slopes below the Gravel and Boulder Clay, south of Cadney Church, and south-east from the termination of the Cadney Gravel toward Poolthorn, and also on the north of the Boulder Clay between Cadney and Howsham.

Dark grey Oxford Clay, with a nodular stone band, is visible beneath superficial deposits in a drain between Froghall, Low Barf, and Kettleby Dyke.

South of Brigg Oxford Clay is imperfectly exposed in Faraway Drain between Kettleby Dyke and Black Bank.

The upper part of the Oxford Clay is exposed in the Railway cutting between Wrawby and Barnetby, and it is also well shown in the cutting between Brigg and Barnetby.

Between Elsham Station and Kettleby Dyke, owing to the irregular encroachments of the superficial deposits and to its being capped by Gravel and Boulder Clay on the hill, the Oxford Clay occurs in a very irregular way at the surface; it separates the older from the newer superficial deposits of the Wrawby district, but in the vicinity of Brigg the newer deposits overlap and conceal it.

The M. S. and L. Railway cutting between Brigg and Kettleby Lodge (toward Barnetby) is more than a quarter of a mile in length, and about 30 feet in the highest part. It is for the most part capped by a thin

accumulation of Boulder Clay. Owing to slips and rainwash this cutting does not present so clear a face as that north of Wrawby; it is composed of dark grey Oxford Clay, weathering a lighter grey, and containing *Gryphæa dilatata* (often of large size) associated with fragments of mudstone, or compact argillaceous limestone; *Ostrea gregaria*, Sow. *Ammonites athletus*, Phil., were also found. The following fossils were obtained by the fossil collector from this cutting:—

Gryphæa dilatata, *Sow.*, *O.*
Inoceramus (cast).
Modiola bipartita, *Phil.*
Nucula ornata, *Quenst.* (cast). *O.*
Thracia depressa, *Sow.*, *K.*
Trigonia (cast).
Ammonites biplex, *Sow.*

In the above list O denotes fossils of Oxfordian and K of Kimeridgian type.

It is possible that the uppermost beds exposed in the cutting may be Kimeridge, but there is no positive evidence of it.

Oxford Clay was exposed in drains, crossing the hill on the south side of this cutting.

The cuttings north of Wrawby commence at about 30 chains from Elsham Station.

In the first and smallest cutting, 15 feet in the highest part, Kimeridge Clay with characteristic fossils is exposed; but, as the distinction between the Oxford and Kimeridge Clays is a purely palæontological one, it is possible that the lowest part of the cutting may represent the top of the former.

The next and largest cutting, spanned by the Bridge of the Brigg and Elsham road, is about 30 feet in the highest part, on the west side of the Bridge. It exposes dark bluish-grey clay and shale, containing large glassy crystals of selenite, iron pyrites, and large oviform septaria, binding ferruginous mudstone (clay stone). Two impersistent argillaceous limestone bands, containing *Ammonites*, occur in the clay on the west side of the Bridge. The upper part of this cutting is proved by fossils to be Kimeridge Clay. The fossils obtained in it are given in the next chapter.

In Catchwater Drain blue clay is exposed; it appears to be Oxford Clay. The following fossils were obtained from it at about half a mile south-west from Elsham Station.

Serpula tricarinata, *Sow.*
Gryphæa dilatata, *Sow.*
Ammonites plicatilis, *Sow.*
,, rotundus, *Sow.*

The boundary between the Oxford and Kimeridge Clays is concealed by Sand north of Elsham Station for about three-quarters of a mile; it then appears to pass beneath the Alluvium of the Ancholme.

The most northerly exposure south of the Humber is at the east end of Winterton Holme Hill, west of Scabcroft, where the lower part of the Oxford clay, blue clay with limestone concretions, is shown.

The following fossils were obtained from the exposure:—

Serpula tetragona, *Sow.*
Avicula inæquivalvis, *Sow.*
Gryphæa dilatata, *Sow.*

The above is the only exposure of Oxford Clay between Elsham Station and the Humber. North of the Humber the Oxford Clay is uncovered by superficial deposits near South Cave, whence it extends to the northern margin of Sheet 86.

CHAPTER XII.

THE RELATIONS OF THE MIDDLE AND UPPER OOLITES.*

In Sheet 86 there is no lithological distinction between the Middle and Upper Oolites.

The Middle Oolites consist of the sandstone and sands of the Kellaways Rock overlain by the blue Clays of the Oxfordian, containing *Gryphæa dilatata* in abundance. As we ascend in the series we find *Gryphæa dilatata* giving place to *Ostrea deltoidea*, and have as yet failed to discover it either in association with or above the horizon of that fossil. Otherwise the Clays are perfectly homogeneous, there being large nodules of argillaceous limestone in them, occurring in bands, to which we are unfortunately unable to attach much significance, owing to the very partial exposures of the Oxford and Kimeridge Clays.

The Railway cutting north of Wrawby appears to be the only exposure furnishing a palæontological boundary between the Clays of the Middle and Upper Oolites. The cutting is three-quarters of a mile north-east of Wrawby.

The following fossils were obtained by the fossil collector from ironstone septaria in the Clays:—

Serpula tetragona, *Sow.*
Glyphæa.
Arca (long sp.).
Astarte carinata, *Phil.*
Avicula inæquivalvis, *Sow.*
Cardium striatulum, *Sow.*
Corbula.
Cyprina?
Exogyra (Gryphæa) virgula, *Def.*
Gryphæa dilatata, *Sow.*
Nucula, n. sp.
„ ornata, *Quenst.*
Ostrea deltoidea, *Sow.*
Thracia depressa, *Sow.*
Trigonia.
Cerithium costigerum, *Piette.*
Ammonites Bakeriæ, *Sow.*
„ rotundus, *Sow.*

To the above we may add *Ammonites athletus*, Phil., and *A. biplex*, ? Sow., previously obtained by Mr. Etheridge from this cutting.

* Since this chapter was in type Mr. T. Roberts' paper on "The Upper Jurassic Clays of Lincolnshire" has appeared (*Quart. Journ. Geol. Soc.*, vol. xlv., p. 545. 1889). The author gives reasons for believing that the Corallian Beds are here represented by clays.

Ostrea deltoidea and *Exogyra virgula* were found in the upper part of the cutting, which would certainly show that Kimeridge clay constitutes that part of it. *Ammonites rotundus*, although elsewhere characteristic of the Kimeridge Clay, is found at a much lower horizon in association with *Gryphæa dilatata* in Catchwater Drain, so it cannot be regarded as a characteristic Ammonite in this area.

Gryphæa dilatata, *Ammonites Bakeriæ*, and *A. athletus*, *Astarte carinata* and *Nucula ornata* seem to be evidences of Oxford rather than of Kimeridge Clay. From this it would appear that the lower part of the cutting is Oxford Clay.

The occurrence of *Exogyra virgula* calls for further remark, because on the continent it is supposed to be characteristic of, and confined to, the Upper Kimeridge, but Prof. Blake finds it to be distributed throughout the Kimeridge Clay in the south of England, and to be more especially abundant about the zone of passage from Lower to Upper Kimeridge. As this fossil has never before been found in Lincolnshire, it raises the following difficulty: if we regard it as marking the upper part of the Lower Kimeridge, then either that division has become very much attenuated or else we must consider the whole cutting Kimeridge Clay, ignoring any significance that may be attached to the several fossils with Oxford Clay affinities obtained from it, and by so doing deprive ourselves of the only section in which any appearance of a junction is obtainable.

On the other hand, we may get rid of the difficulty occasioned by the discovery of this single specimen, on the ground that its range is not so restricted as has been supposed, and admit that its presence here is proof of the continued downward extension of its range as we proceed northward through England.

Of these opinions the latter appears the most reasonable; we therefore regard the fossil as occurring in the basement beds of the Kimeridge Clay, the lower part of the cutting being Oxford Clay.

Although *Ammonites rotundus*, a Kimeridge Clay form, has been found in association with *Gryphæa dilatata* considerably below the horizon of the Kimeridge Clay section; to take it as evidence, we should have almost to cut out the Oxford Clay, north of Brigg, and permit its sudden thickening southward.

In this area as we find *Gryphæa dilatata* always lower in position than *Ostrea deltoidea*, if we attach no significance to its occurrence we can have no indication of a palæontological boundary between the Clays. If, however, a line be drawn on the Map by the discovery of *Gryphæa dilatata*, however indefinite such a line may be, it seems roughly to conform to a stratigraphical horizon, and being prolonged to the southern margin of Sheet 86 enters Sheet 83 within the region indicated by Mr. Jukes-Browne in the Explanation of that Sheet as the zone of passage between the two Clays.

Palæontologically, then, we may take *Ostræa deltoidea* as characteristic of Kimeridge, and *Gryphæa dilatata* as confined

practically to the Oxford Clay in this area. The line that the discovery of these forms (in Sheet 86, south of the Humber) enables us to draw is necessarily an exceedingly vague one, but it is based on the most reliable evidence we can obtain.

The base of the Kimeridge Clay may be said to run through Elsham Station in the direction of Wrawby Mill, and thence by Howsham and North Kelsey, near South Kelsey, passing into Sheet 83 on the south of Thornton-le-Moor.

The only pit touching this boundary line is in a Brickyard by the side of the Canal at about half a mile north of South Kelsey Church. The following fossils were obtained by the fossil collector from the blue clays exposed in this pit:—

Serpula.
Rhynchonella, near to R. oolitica, *Dav.*
Gryphæa dilatata, *Sow.*
Pholadomya æqualis, *Sow.*
Alaria trifida, *Phil.*
Ammonites plicatilis, *Sow.*
„ rotundus, *Sow.*

To the above we may add fossils obtained from the pit by Mr. Jukes-Browne, which are given by him with a section of the exposure in the succeeding chapter (on Kimeridge Clay).

Ceromya.
Gryphæa, like dilatata, *Sow.*
Ostrea, like deltoidea, *Sow.* (fragments).
Thracia depressa, *Sow.*

From the above lists it would appear that the junction between the Middle and Upper Oolites is, or was, exposed in this pit; for, dismissing *A. rotundus*, which we have found to range downward into the Oxford Clay, the first list shows Oxford Clay affinities, whilst some of the specimens mentioned by Mr. Jukes-Browne seem to indicate Kimeridge Clay.

CHAPTER XIII.

UPPER OOLITES.

KIMERIDGE CLAY.

Stratigraphically, as we have shown, it is impossible to fix on a line of junction that could be traced on the ground in the great Clay series which overlies the Kellaways Rock and passes under the Cretaceous rocks of the Wolds.

Palæontologically, as we have seen, there is a distinction between the upper and lower parts of the Clay, but the sections, with the exceptions of the three Railway cuttings near Wrawby, afford a very poor assemblage of fossils. There is one Kimeridge Clay section in which *Ostrea deltoidea* has been obtained, as also seven species of *Ammonites*, one of which, *A. Kœnigii*, may be regarded as an Oxford Clay form.

The smaller cutting, near Elsham Station (the section just referred to), north of Wrawby, is about 18 chains in length, and 15 feet in the highest part; towards its extremities, the cutting is masked by Sand and talus; it exposes dark grey shaly Clay, proved by the fossils obtained within 8 or 9 feet of the top of the cutting in the highest part, to be Kimeridge Clay, not distinguishable in colour from the Oxford Clay in the neighbouring cutting. The occurrence of the Kimeridge Clay in this place is due either to a deflection of the general strike of the Oolites in rough parallelism to the outcrop of the Cretaceous beds of Elsham and Worlaby, or to a local undulation throwing it in, in a trough; in either case it is possible that the base of the cutting in which, owing to talus, &c., no fossils were obtained, may be in Oxford Clay. In a band of septarian nodules, in the Clay in the upper part of the cutting, the following fossils were obtained and identified by Mr. Etheridge; those in the clay being very delicate, and *Avicula* being most plentiful:—

Serpula tetragona, *Sow.*
Anomia?
Avicula (like expansa, *Phil.*).
Gervillia.
Inoceramus expansus, *Blake.*
Ostrea deltoidea, *Sow.*
Perna.
Ammonites biplex, *Sow.*
„ sp.
Belemnites nitidus, *Dollf.*

The Survey fossil collector visited this cutting on several occasions. The following is the list of the species obtained by him :—

Serpula tetragona, *Sow.*
Cidaris spinosa.
Arca.
„ (Cucullæa) longipunctata, *Blake.*
Avicula inæquivalvis, *Sow.*
„ Münsteri *Goldf.* (many specimens).
Cardium striatulum ? *Phil.*
Ostrea deltoidea, *Sow.*
Pecten lens, *Sow.*
Pholadomya æqualis., *Sow.*
Thracia depressa, *Sow.*
Alaria trifida, *Phil.*
Alaria (fragment).
Ammonites alternans, *Von Buch.*
„ biplex, *Sow.*
„ plicatilis ?, *Sow.*
„ near to A. cymodoce, *D'Orb.*
„ Kœnigii, *Sow.*,
„ rotundus, *Sow.*
„ Kappffii, *Oppel.*
Belemnites (phragmacone).
Fish vertebra.

In this list there does not appear to be any particularly characteristic Oxford Clay form, except, perhaps, *A. Kœnigii.*

In the larger cutting, *Ostrea deltoidea* and *Exogyra virgula* were found ; also *Ammonites rotundus.* The list of fossils obtained in it is given in the preceding chapter. The boundary, or junction line, must occur in this cutting, as characteristic Oxford Clay fossils are numerous ; but how far down in it we should place the base of the Kimeridge is doubtful.

From Ferriby to Elsham Sand and gravel conceal the lower part of the Kimeridge Clay, but it forms an irregular band at the base of the steeper slope of the Wolds, just above Horkstow, Saxby, Bonby, and Worlaby, as also in the following districts :—Between Melton Ross and Wrawby Mill ; Melton Ross and Grasby ; from Audleby, near Clixby, to Caistor ; and from Nettleton to the southern margin of Sheet 86. On the north of the Humber from Welton to the northern margin of Sheet 86 Kimeridge Clay forms a narrow band on the slope below the Chalk.

Kimeridge Clay comes to the surface on the sides of the valleys breaking up the eastern part of the Boulder Clay tracts, near Howsham, North Kelsey, South Kelsey, and Thornton-le-Moor.

The following notes relate to the few exposures of the Clay besides those of more importance mentioned above, which have furnished fossils as we proceed northward:—

At Claxby Moor Brickyard blue Clay with ironstone concretions is exposed. The following fossils were obtained in it:—

Astarte?
Corbula.
Cypricardia?
Nucula.
Ammonites rotundus, *Sow.*

Limestone concretions, in the Clay exposed at Holton Brickyard, three-quarters of a mile south-east of Holton Church, furnished the following:—

Arca.
Nucula.
Thracia depressa, *Sow.*
Cerithium torticostatum, *Blake* (?=C. costigerum, *Piette*).
Ammonites plicatilis, *Sow.*
,, rotundus, *Sow.*

From Moortown Hill Clay pit, three-quarters of a mile west of Moortown Station, the following fossils were obtained:—

Serpula tetragona, *Sow.*
Arca longipunctata, *Blake.*
Avicula inæquivalvis, *Sow.*
Ostrea deltoidea, *Sow.*
Pecten lens, *Sow.*
Alaria trifida, *Phil.*
Ammonites, near to A. cymodoce, *D'Orb.*
,, near biplex, or rotundus (abnormal form).
,, rotundus, *Sow.*

Mr. Strangways furnishes the following note:—

From the Clay below the Neocomian Sandstones, about a mile south-west of Nettleton Church, the fossil collector obtained the following species:—

Terebratula ovoides, *Sow.*
Cucullæa.
Isocardia.
Lucina.
Panopæa.
Ammonites biplex, *Sow.*
,, plicatilis, *Sow.*

C. F. S.

The section, which appears to be on, or near, the junction between the Kimeridge and Oxford Clays, is thus described by Mr. Jukes-Browne:—

A brickyard at South Kelsey, half a mile north of the Church, exposes the following section:—

	Feet.
Soil and Chalky Boulder Clay in shallow pockets	2
Clean blue shaly clay	2
Blue shaly clay full of selenite in small crystals	4
Clay with lines of septaria, about 3 feet apart and larger, crystals of selenite	10

The Clay is decidedly shaly, especially that part which is full of selenite; but I was informed by the foreman that about 2 feet below the bottom of the open working there is "strong blue dicey clay of a different nature to that above." Fossils are not very abundant, but I found large Ammonites, *Thracia depressa*, *Ceromya*, and fragments of *Ostrea*, some like *O. deltoidea* and some like *Gryphæa dilatata*.

A. J. J.-B.

The fossils obtained by the fossil collector from this pit are given in the preceding chapter.

North Kelsey Brickyard is a mile north-east from North Kelsey. The Clay contains limestone concretions from which the following fossils were obtained :—

Serpula tetragona, *Sow.*
Avicula inæquivalvis, *Sow.*
Corbula.
Modiola bipartita, *Phil.*
Opis.
Placunopsis ?
Alaria trifida, *Phil.*
Ammonites rotundus, *Sow.*

To the north of the Elsham Railway sections, at nearly a mile and a half north from Elsham Station, blue Kimeridge Clay is exposed in the Worlaby Brickyard. *Thracia depressa* and *Ammonites rotundus* were obtained in it.

The Kimeridge Clay was reached in sinking the shaft of the Acre House Mine at the southern border of Sheet 86. It consisted of "very dark coloured highly bituminous shaly Clay," *see* section on p. 107.

CHAPTER XIV.

CRETACEOUS ROCKS.

The Cretaceous rocks occupy a very large area in Sheet 86, nearly half of the Map, extending eastward from their outcrop on the escarpment of the Wolds.

In this area, however, their occurrence at the surface is very much more restricted; a line drawn from the south-east corner of the Map, by Riby, Brocklesby, Thornton Station, and Barrow, to the Humber at Barton, limits the superficial occurrence of the Cretaceous rocks; to the east of it they are entirely concealed by Glacial deposits, which in their turn pass under the Alluvium of the Humber. On the north of the Humber, in the Boulder Clay and Alluvial districts, east of Hessle and Kirk Ella, no Cretaceous rock has been noticed at the surface in this Map,

The Cretaceous area attains its maximum breadth of 8½ miles in the south part of the Map, south of Caistor, Swallow, and Irby; at Melton Ross, through the encroachment of superficial deposits, it is not much more than a mile across; between Melton Ross and Barton-upon-Humber it attains a breadth of from 5 to 6 miles. At Barton the Cretaceous area of North Lincolnshire is separated from that of South Yorkshire by the Alluvial and Glacial deposits of the Humber valley from which the rocks emerge on the north side of North Ferriby, and extend thence to the northern margin of the Map, where the breadth of area occupied by them is about 5 miles. The Cretaceous rocks* are divided as follows into—

Upper Cretaceous, or Chalk Series,
Lower Cretaceous, or Neocomian Series.

Lower Cretaceous.

The Lower Cretaceous series occupies a very small superficies. It occurs on the middle and upper slopes of the escarpment of the Wolds; but it is only when capping nabs or promontories from which the overlying Chalk has been denuded, as near Nettleton Lodge, at Caistor, and on Barnetby Gorse Hills, that its outcrop attains any noticeable breadth.

Owing to the overlap of the Upper, upon the Lower, Cretaceous series the latter is by no means persistent; it disappears beneath the Chalk at Clixby, reappearing on Barnetby Gorse Hills, whence it extends in a narrow band to Worlaby, where it is again over-

* Detailed accounts of the classification of the Cretaceous rocks, which it will be unnecessary to repeat here, will be found in the Memoir on Sheet 83, Chaps. X. and XI., 1888; Memoir on Sheet 84, Chaps. III. and IV, 1887; *see* also A. Strahan, *Quart. Journ. Geol. Soc.*, vol. xliii., p. 486, 1886.

lapped, and does not reappear at the surface from Worlaby to the northern margin of the Map. The Lower Cretaceous beds have been exposed by denudation in the south part of the Map in the valleys of Rothwell and Thoresway, where they form two long narrow inliers.

The nomenclature of the Lower Cretaceous or Neocomian rocks of Lincolnshire adopted by the Geological Survey, in great part from Prof. Judd, is given in the following table:—

Neocomian	Tealby Beds.	Carstone
		Tealby Limestone.
		Tealby Clay.
		Claxby Ironstone.
		Spilsby Sandstone.

Mr. Strangways, who mapped the Neocomian beds on the escarpment of the Wolds, describes them as follows:—

These beds have a total thickness of between 80 and 90 feet on the south of the Map, but several of the divisions thin out rapidly to the north and disappear before the formation is overlapped by the Chalk about 2 miles to the north of Caistor.

The best section of the entire series is that obtained from the shaft at the Acre House Mine,* which, commencing in the Chalk, penetrates all the beds down to the Kimeridge Clay. The section is as follows:—

	Ft.	In.
Soil - - - - -	2	6
White Chalk - - - 9 ft. to	10	0
Beds of yellow clay and red marly Chalk -	10	0
Red sand [Carstone] - - -	10	0
Limestone rock, hard, and blue-hearted [Tealby Limestone] - - -	14	0
Blue clay, with the same fossils as the limestone above (*Pecten cinctus* abundant) [Tealby Clay] - - - -	40	0
Ironstone, soft and earthy above, solid and finely oolitic below (only the lower part is worked) [Claxby Ironstone] - 13 ft. to	14	0
Coarse greenish-white sands, in places indurated into hard sandstone rock [Spilsby Sandstone] - - - 6 ft. to	7	0
Very dark-coloured, highly bituminous, shaly clay. A thin bed at the top is remarkable for its highly inflammable character, and greatly resembles the Kimeridge coal of the South of England.		

* The section is copied from the one given by Prof. Judd in his valuable paper on these beds, *Quart. Journ. Geol. Soc.*, Vol. xxvi., p. 331, 1870. The present manager, at the time of our survey, had not any additional information to give. The Spilsby Sandstone, as here recorded, is thinner than at the outcrop immediately to the west (*see* Section on page 109).

It will be seen from the above section that there are five lithological subdivisions of the Neocomian Beds; these Prof. Judd places in three groups:—*The Upper Sands; the Tealby Series*, including the limestone, clay, and ironstone; *The Lower Sand and Sandstone.*

Spilsby Sandstone.

The Spilsby Sandstone, which forms the basement bed of the formation, is one of the most constant of the series, and, from its position immediately on the dense clays of the Kimeridge, usually forms, except where hidden by superficial deposits, one of the most conspicuous features.

These sands have a thickness of from 6 to 30 feet and form a prominent bank on the hillsides about Nettleton and at Elsham. They consist principally of soft gritty sand, but in places, as at Elsham and in Nettleton Dale, indurated into a much harder rock, which either stands out in a small feature or lies about in detached blocks, some of which, at Elsham, are of considerable size; these harder blocks also contain a few fossils, principally *Pectens*, and at Elsham a fragment of an Ammonite was found. At Audleby the upper part of these sands is very stony and coarse, the stones being as big as split peas and consisting principally of white quartz and Lydian stone, containing apparently no phosphates or iron flakes. At Acre House this sand, being exceedingly sharp and clean, is quarried and sent away by rail.

Claxby Ironstone.

Immediately resting on these sands we have the Claxby Ironstone, the most important bed, both commercially and palæontologically, of the whole series. To the south of Nettleton this bed has a maximum thickness of 14 feet, but thins out to the north and disappears a short distance beyond Caistor. It may be divided lithologically into two portions, a dark red earthy ferruginous rock, more or less shaly and concretionary and greyish-red oolitic beds, which seem to be composed of beautifully polished grains of oxide of iron cemented together in a calcareous sandy matrix; these latter are the beds which are worked for iron; they are evidently very calcareous, as may be seen from the fine crystals of carbonate of lime which have been obtained from the Acre House Mine. These beds, especially the earthy concretionary part, are very fossiliferous and remarkable for the abundance of large specimens of *Pecten cinctus*, which along certain lines are crowded together in great profusion.

The following fossils have been obtained by the Survey fossil-collector from the hill south of Nettleton:—

Serpula gordialis, *Schl.*
Cucullæa Gabrielis, *Leym.*
Exogyra sinuata, *Sow.*
Lucina.
Pecten cinctus, *Sow.*
Trigonia (fragment).
Belemnites lateralis, *Phil.*
,, semicanaliculatus, *Blainv.*

The following have been obtained from Acre House Mine:—

Serpula antiquata, *Sow.*
" filiformis, *Sow.*
" plexus, *Sow.*
Vermicularia.
Waldheimia hippopus, *Röm.*
" Juddii, *Walker.*
" (? tamarindus, *Sow.*).
" (? Walkeri, *Dav.*).
Arca Raulini, *Leym.*
Cucullæa Gabrielis, *Leym.*
Exogyra conica, *Sow.*
" sinuata, *Sow.*
Lima, n. sp.
Modiola, (sp.).
Panopæa.
Pecten cinctus, *Sow.*
" orbicularis, *Sow.*
Trigonia nodosa, *Sow.*
" sp.
Pleurotomaria.
Ammonites noricus, *Schl.*
" nutfieldiensis, *Sow.*
Belemnites lateralis, *Phil.*

C. F. S.

The section of the Claxby Ironstone beds at the workings on the Cretaceous escarpment south of Acre House gives the following descending sequence:—

		Ft.	In.
Tealby Clay -	Clay, partly ferruginous.		
Claxby Ironstone.	Rubbly brown oolitic ironstone, forming a bedded rock, much decomposed in places. The beds are coated on the surface by limewash (? stalagmitic) - - about	15	0
Spilsby Sandstone.	Bed of coarse sandstone, calcareous in the upper part - - - 2 to	3	0
	Coarse grey and greenish sand with large grains disseminated throughout - about	15	0
Kimeridge Clay.			

W. A. E. U.

Mr. Strangways continues as follows:—

The ironstone beds are well exposed on the flank of the hill between Nettleton and Acre House, where they form a small scar in the hill side.

At Caistor they are seen in the ditch by the roadside to the north-west of the town; and at Hundon, where these beds have been dug to try the value of the ore, there are about 8 feet between the sandstones and the calcareous shales above; north of this the rock has not been observed, and it is probable that it disappears somewhere in the neighbourhood of Audleby.

Tealby Clay.

The Tealby Clay, above the ironstone, follows the outcrop of that bed, making, south of Nettleton, a clayey slope above the drier ground of the ironstone and sands below. North of Nettleton it forms a mere band, which is seen in the road north of Caistor; at Hundon, where there are about 12 feet of grey and yellow clays full of oolitic iron fragments and white concretions, and at a few other places; but it is nowhere very well exposed, and does not call for particular notice.

South of Elsham, however, these clays come in again and form a marked band between the Chalk and the Neocomian Sands along the fields above

the Keeper's House. There are here one or two old pits in them and they are seen below the Red Chalk in the lane just south of the village, where they are about 3 or 4 feet thick.

Tealby Limestone.

The Tealby Limestone, which attained its greatest thickness in the Map to the south, gradually thins away northwards.

In the shaft at Acre House it is about 14 feet thick, and it forms a considerable spread on the hill tops about Nettleton Lodge and just south of Nettleton. At the head of the valley to the south of this it seems to have been quarried in former times, although the irregular mounds dotted about may be the result of old ironstone workings.

A considerable portion of the town of Caistor stands on this rock, and it spreads out on the hill between here and Hundon, but north of this the bed becomes very thin, and just south of Audleby, where there are some nodular calcareous beds with oolitic grains in shale (apparently the last remnant of the limestone), it finally disappears.

Carstone.

The Carstone is generally seen immediately below the Chalk, wherever there is a good section, as far north as Clixby, and again at Melton Ross.* It appears to a certain extent to be unconformable to the beds below, as at these places the other beds are very thin or have entirely gone.†

These sands, which have rather the appearance of a fine gravel, are composed of rounded and angular fragments of quartz, Lydian stone, and small phosphatic nodules with irony concretions. They are usually soft and friable, and consequently it is only in a few places that good sections are obtained, although from the pebbly character of the bed it is not difficult to follow its outcrop.

The thickness of these sands increases with the dip of the strata to the east, for while they are only about 10 feet thick at Acre House there are 20 feet of them in the valley south-west of Thoresway. Along the escarpment, however, these beds are usually very thin and form a mere line in the country north of Caistor. The best sections are in Nettleton Dale near the two farms on the east side of that valley.

At the southernmost of these farms the following section is exposed:—

	Ft.	In.
Pale red Chalk - - - - - -	1	6
Red Chalk in blocks with quartz pebbles in lower part	2	6
Yellow, ferruginous, clayey sandstone, with numerous phosphatic nodules, about ¾ × ½ × ¼ inches - -	4	0
Sandstone with scattered pebbles - - -	2	0
Bank obscured by rubbish, probably mostly sands, about - - - - - - -	8	0

* Between these points we have not found any trace of Neocomian beds, although Mr. Judd mentions the occurrence of the Lower Sands at Searby. *Quart. Journ. Geol. Soc.*, Vol. xxiii., p. 247.

† Mr. Jukes-Browne remarks:—The easterly thickening of the Carstone and the fact that the Red Chalk rests on the Tealby Limestone at Audleby and on the Lower Sands at Melton Ross, suggests to me that the Red Chalk dissociates itself from the Carstone, and oversteps the whole Lower Cretaceous Series, which may continue without interruption beneath the Chalk.

At the barn opposite Nettleton Grange the following section, although less clear than that above, may be made out:—

	Ft.	In.
Red Chalk much broken and disturbed as if by slipping - - - - - -	4	0
Sandstone, gritty below, pebbly above; numerous rolled phosphatic nodules, about ¾ × ½ inch, with a few scattered ones as large as 2½ × 2 × 2. These larger nodules have oolitic ferruginous grains, *Belemnites* and Bivalves amongst them - - 8 ft. to	12	0
Limestone in loose blocks - - - about	8	0

At Melton Ross there are coprolites and rolled pebbles with fragments of *Ammonites* in the base of the Red Chalk, which is here very sandy and contains quartz pebbles, *Belemnites*, &c. The Red Chalk here rests directly on the Spilsby Sandstone.

At Elsham there is a thin clayey grit containing phosphatic nodules immediately below the Red Chalk, with the usual quartz pebbles, which seems to be the last representative of the Carstone, for north of this the bed has not been observed.

C. F. S.

Inliers.

The following notes are by Mr. Jukes-Browne.

There are two long and narrow inliers of the Carstone near the southern border of Sheet 86. These are exposed in two of the deep valleys which drain the dip-slope of the Chalk.

The southernmost inlier extends from Thoresway Warren to within half a mile of Croxby Pond, a distance of 3½ miles; it is nowhere more than 400 yards wide, and only attains that width at Thoresway, where the valley forks into two branches. The only good section is at the fine springs which supply the reservoir at Thoresway, south-west of the church; these have been cleared out and the following beds exposed in a nearly vertical cliff:—

		Feet.
Chalk.	White Chalk, becoming pink at bottom - -	3
	Red Chalk in several layers, passing down into dark red marl and yellow marly sand (1 foot) - -	7
Carstone.	Coarse yellow and brown sand with small pebbles of quartz, a few phosphates, and bits of black iron ore - - - - - - -	14
	Band of pebbles about the size of cob-nuts, chiefly quartz and lydianite - - - -	1
	Hard, compact, brown sandstone, consisting of small angular quartz grains set in a ferruginous matrix, springs issuing from the base - - -	5
		30

The beds are nearly horizontal. There is here no definite line between the Red Chalk and Carstone, the one seeming to pass gradually into the other; but the stratigraphy affords strong evidence that there is really an overstep of the lower beds by the Red Chalk, and, possibly an unconformity between the Carstone and the Red Chalk.

The junction of the two formations can also be seen in a small sand pit by the roadside half a mile south-east of the Church, where I observed the following section:—

	Feet.
Nodular Red Chalk	3
Red marl with lumps of hard Red Chalk full of *Belemnites* and *Terebratula biplicata*	1
Mottled, marly sand, yellow, brown, and purple, with large nodules of whitish sandy phosphate	1
Yellowish-brown sand with small pebbles of quartz and a few broken and rolled phosphates	8

The thicknesses given above are approximate only, since there is a complete passage from each stage to the other.

Similar brown sand can be seen above the spring on the north side of the valley midway between Thoresway and Croxby, but the section is obscured by talus.

The second inlier occurs in the Rothwell valley, but is much smaller, its extreme length being about two miles, and the Carstone is to a great extent concealed by the wash of chalky gravel brought down by rain from the slopes on either side.

At the spring head, half a mile south of Rothwell Church, a trench exposes the *débris* of Red Chalk overlying dark brown sand full of rounded quartz pebbles and rolled phosphates, the whole compacted by infiltrations of lime and iron into a hard rocky mass, which might be called a conglomerate.

Lower down the valley and about a furlong south-east of the Church another spring issues from beneath a mass of hard brown sandstone in regular beds; about 9 feet is exposed and there may be a depth of 5 or 6 feet above before the outcrop of the Red Chalk is reached.

At the farm in the valley a mile east-north-east of Rothwell a well was sunk through gravel into the Carstone. (*See* Appendix, p. 216.)

A. J. J.-B.

At Rothwell Lodge, a quarter of a mile north-east of the church (not the farm so named on the map) a well was sunk through sand into soft Oolitic Ironstone.

CHAPTER XV.

CRETACEOUS ROCKS—*continued.*

UPPER CRETACEOUS.

The Upper Cretaceous or Chalk series, in this area is composed of four members in the following descending order:—

Upper Chalk, without Flints.
Middle Chalk, with Flints (except near the base).
Lower Chalk, or Grey Chalk.
Red Chalk.

The uppermost member of this series may, and probably does, occur beneath the Alluvium and Glacial deposits, which cover so large an area in the north-eastern part of Sheet 86; but it is nowhere visible at the surface.

The Middle Chalk, or Chalk with Flints, occupies nearly the whole of the area covered by the Cretaceous Rocks at the surface. The Lower, or Grey, Chalk attains a maximum breadth of outcrop of only a mile and a quarter on the southern margin of Sheet 86, on its main outcrop, which to the north of Nettleton Lodge is seldom as much as a quarter of a mile broad. The Lower Chalk is also at the surface on the borders of the Neocomian inliers of Rothwell and Thoresway and extends from the former to beyond Swallow and up the Cabourn valley. The Red Chalk is thin and is confined to a narrow line on the borders of the Neocomian beds.

The Chalk with Flints forms a cliff on the east of the Wolds, against which the Glacial Deposits which conceal it on the east abut; in places these deposits extend westward over the Chalk and up the valleys breaching it.

RED CHALK.

The Red Chalk in South Yorkshire and North Lincolnshire probably varies in thickness from 4 to about 6 or 7 feet. It consists of a nodular limestone in several beds, or of hard, nodular, red Chalk in a marly matrix. The outcrop is easy to follow, for over the greater part of the area the Red Chalk marks the boundary between the dry ground of the Chalk and the wet lands of the clays below.

Commencing at the northern end of the district, the first exposure is seen at the corner of Woo Dale, just north of Brantingham, where a small landslip has exposed the Red Chalk resting on clay with *Gryphæa dilatata*.

Copious springs are also thrown out on the east side of the village along the line of outcrop. At the Hall the outcrop is more obscure, but it will probably be just below the house, as the cellars of that building are said to have been excavated in Chalk.

At Welton Springs there is a good exposure of the Red Chalk, and, judging from the nature of the ground, the outcrop passes just above Welton House; but beyond this it is covered by Boulder Clay, and there is no evidence as to where it strikes the Humber.

The Red Chalk probably rises from the Humber at about half a mile north-east of Ferriby Hall; the grey marly beds seen on the shore at this point cannot be far above it, but from the covering of Boulder Clay and the slipping of the Chalk above towards the Humber, the rock is not seen till we reach the neighbourhood of Horkstow. In the roads above this village there are several exposures showing beds of Red Chalk containing pebbles, &c. and having the character of a conglomerate. Beyond this the Red Chalk itself is not seen for some distance, but the base of the Chalk is well marked by the numerous springs which break out above Grange, Saxby, and Bonby, above which places the bed is exposed here and there.

At Worlaby, again, there are several good sections showing the Red Chalk, both in the road on the north side of the village, where the bed, which has a thickness of from 3 to 4 feet, is seen below the barn marked on the Map; and also in the road near the Hospital; and again in the wood, above the Old Brickyard, at which last place there was a good section showing 5 feet of Red Chalk below the Grey Chalk; at the junction, which was sharply defined, there was a foot of Pink Chalk.

Beyond this the line is easy to trace above the Neocomian sands, which now become more prominent, and the Red Chalk may be seen in both the roads leading up out of Elsham.

On the north side of Barnetby, the hill being covered by superficial deposits, the outcrop becomes excessively obscure, and there is no means of estimating exactly how far it extends over the hill towards Barnetby; it is just possible that the outcrop runs behind this mass of Boulder Clay towards Melton Ross. At the spring on the south side of the Railway, at this latter place, beds of yellow Chalk, containing quartz pebbles and *Belemnites*, are seen. From this point the outcrop of the Red Chalk skirts along the edge of the Wolds, above the villages of Barnetby, Bigby, Somerby, Searby, Owmby, and Grasby, but is not well seen anywhere in this region, although it is not difficult to trace it above the clay lands below. South of this the Neocomian beds again appear and the line is not in all cases quite so well defined as it is further north; the bed is, however, seen at a few places in the neighbourhood of Caistor.

In the Nettleton valley there are again some good exposures of the Red Chalk, which is seen above the barn opposite the Grange, where the beds are rather disturbed, probably from slipping, and also at the Farm further up the valley; this is, perhaps, the best section of it in the Map, the Red Chalk being exposed resting on the sandy beds of the Neocomian, with a considerable thickness of Grey Chalk above; the Red Chalk is here about 4 feet thick (*See* p. 111.).

South of this the Red Chalk does not present any good sections, but fragments of the rock are scattered along the hill edge above Acre House and in the shaft at that place it is said to have a thickness of 10 feet, but this must include other beds besides the true Red Chalk.

C. F. S.

The occurrence of Red Chalk fringing the Neocomian inliers, in the Thoresway and Rothwell valleys has been described in the previous chapter. South-west of Thoresway Church it was found to be 7 feet in thickness.

LOWER (OR GREY) CHALK.

The following description of the *Lower (or Grey) Chalk* is furnished by Mr. Jukes-Browne:—

This division consists for the most part of grey or greyish-white chalk, in thin beds, hard, and often nodular, with thin partings of shaly chalk at intervals. The following appears to be the usual succession of beds in this part of Lincolnshire, taken in descending order:—

	Feet.
6. Grey shaly, marl, soft and crumbling, sometimes including a layer of whitish chalk, about -	2
5. Hard greyish white chalk with occasional thin layers of shaly marl, about - - -	36
4. Firm grey chalk passing down into rough nodular chalk with some green-coated nodules, about - - - - -	3
3. Rough greyish-white chalk in thin beds with shaly partings, about - - -	26
2. Hard grey gritty and shelly stone in massive beds, about - - - - -	4
1. Hard compact yellowish pink chalk, about 1 or	1½
Total about - - -	72

The lowest of these beds (No. 1) is the equivalent of the so-called "Sponge Bed" of Hunstanton, and the shelly stone above (No. 2) is identical with the "Inoceramus Bed" of that locality and is equally full of broken fragments of Inoceramus shell. No. 3 is similar to the chalk which occurs in a similar position in Norfolk and South Lincolnshire, and these three sub-divisions appear to be the equivalent of the Chalk Marl.

The grey chalk (No. 4) occupies the position of the Totternhoe stone and is believed by Mr. W. Hill* to be its equivalent, a correlation which was not thought of at the time Lincolnshire was surveyed, because the manner in which the Lower Chalk of Cambridgeshire passed into that of Norfolk and Lincolnshire was not then known.

The greyish white chalk (No. 5) is that which is partly coloured pink near Louth, but no such colouration has been observed in North Lincolnshire. *Discoidea cylindrica* is not uncommon in these beds.

The dark grey marl (No. 6) is always a conspicuous feature in the quarries which cut through it. The view that this bed was the continuation of the marls of the Belemnitella plena zone,

* *Quart. Journ. Geol. Soc.*, vol. xliv., p. 825.

suggested in the explanation of Sheet 84, has been confirmed by Mr. Hill* who found the characteristic Belemnite in the great quarry near Barton on Humber.

The main outcrop of the Lower Chalk enters Sheet 86 to the south-east of Acre House, and the first exposure is in a pit by the roadside one mile east-south-east of that place; the beds exposed being probably those numbered 4 in the preceding account, as they consist of greyish white Chalk, thin-bedded, and breaking into loose lenticular lumps, with partings of grey shaly marl; about 20 feet are shown.

Grey Chalk was found by Mr. Strangways overlying the Red Chalk in the quarry near the farm 5 furlongs east of Nettleton Lodge; this would include the *Inoceramus* Bed and overlying chalk, but I did not visit the section.

The quarry by the roadside 6 furlongs east of Nettleton Church exposes the shale band (No. 6) with some of the beds above and below, the section in 1883 being as follows:—

	Feet.
Soil	1
Hard buff chalk with shaly bands	5
Softer marly chalk	2½
Soft grey shale, light-coloured at top and bottom, with a dark purple-grey band in the middle	1½
Very hard cream-white chalk in regular beds	5
Talus concealing the rest	20

The top of the hard rock below the shale is nodular and uneven, as if worn and acted upon by currents of water, and shale is deposited between the interstices of the nodular lumps, which are stained yellow outside; in some places the base of the shale is sandy or gritty, with loose nodules or pebbles of chalk which can be scraped away so as to expose a surface of hard chalk below.

At Grasby, near the Church, there is a quarry giving an interesting section of the beds near the middle of the Grey Chalk; these are:—

	Feet.
Greyish-white chalk, blocky, and not very hard	20
Hard, rough, nodular chalk	1
Shale and loose chalk	0½
Hard, grey, sandy stone, containing large Ammonites, and marked at the base by nodules of decomposed pyrites (the grey bed of Mr. W. Hill)	3½
Marly chalk, in thin beds, with partings of shale	12

A fault traverses the pit striking north-west and south-east and throwing the upper beds down against the lower; these upper beds contain large lumps of what seems to be marcasite replaced by selenite, in large lozenge-shaped crystals. The grey stone is the bed regarded as the equivalent of the Totternhoe Stone. At the cottage near by, the well is 30 feet deep; it is sunk through chalk into the Red Chalk. There are old pits by the side of the high road in higher beds, and at the cottages about a furlong north of the Church, on the high road, the well is said to be 90 feet deep into "Red rock."

The following notes on the sections between Grasby and Ferriby are supplied by Mr. Strangways, who surveyed this portion of the escarpment:—

In a quarry above Barnetby about 25 feet of the Lower Chalk are seen. The Grey Chalk is well seen along the road at the parsonage; and at Elsham Hill about 25 feet of it is seen in a quarry. At Worlaby the

* Loc. cit. p 329.

lower beds are seen above the Red Chalk, in the wood above the old brickyard, and in the quarry above the Hospital: marly grey chalk is also seen in the Barn quarry at Worlaby. . . .

On Bonby Hill grey chalk with *Inoceramus* is found.

The dark shaly band (No. 6) is seen in all the three large quarries facing the Humber between Ferriby and Barton on account of the southerly dip, which increases very much to the north, as if we were approaching a large fault. In the largest and easternmost quarry this band dips westward at 2° across the quarry face; but in the side of the road leading to it the angle of dip appear to be about 15°.

C. F. S.

In 1883 and in company with Mr. Strangways I visited this large quarry, the entrance to which is a mile north-east of South Ferriby Church; thence an excavation has been carried southwards into the hill for a length of more than a quarter of a mile, with a width of some 200 yards; the height of the quarry face at the southern end is about 80 feet, and the section here exposed is as follows:—

		Feet.
Middle Chalk.	Hard white chalk with flints (inaccessible) - about	40
	Compact creamy-coloured chalk - - -	2
	Shale and shaly chalk - - - -	0½
	Hard, yellowish-white, gritty chalk, full of *Inoceramus*, in regular massive beds 12 to 18 inches thick, with partings of shale - - -	11
Lower Chalk.	Soft grey shaly marl darker below, with a thin course of shaly chalk in the middle - -	2
	Greyish white thin-bedded and shaly chalk -	18
	Course of hard, compact, whiter chalk - -	2
	Grey nodular chalk with irregular seams of shale -	6

Nothing like the pink beds of the Louth section are seen here, but the hard yellowish or cream-coloured chalk with its basement band of shale are an exact counterpart of the beds above the pink bands near Louth, and are therefore more persistent in their extension northwards.

The account given by Mr. Hill differs slightly in the particulars of the Lower Chalk. He obtained specimens of *Belemnitella plena* from the soft shaly marl.

Along the outcrop north of the Humber there are but few exposures, but the following account is quoted from the recent paper by Mr. W. Hill:—*

"The first exposure of any part of the Lower Chalk worthy of note, north of the Humber, is in the Greystones pit about three-quarters of a mile north of the village of Melton near Welton. Only a few feet of the Grey Chalk are exposed above the talus slope which now greatly obscures the face, but the Belemnite marls are well shown in the upper part of the pit. . . . Grey chalk is seen in a cutting on the Beverley road, near Brantingham, and again in a small pit on the hill-side nearly a mile north of South Cave and in a cutting of a road leading up to the Wolds near by.

"But no exposure of any importance occurs till the cuttings of the railways to the east of South Cave Station are reached.†

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* *Quart. Journ. Geol. Soc.*, vol. xliv., p. 338.

† These are just outside Sheet 86, near the southern edge of Sheet 94, S.W.

The sides of the cuttings are obscured by débris &c. which renders a detailed description somewhat difficult, nor can the whole series be seen in a continuous section. . . . The first part is taken 85 yards west of the bridge over the line near the entrance to a short tunnel under Sugar Loaf Hill."

The following is slightly altered from Mr. Hill's section :—

		Ft.	In.
Middle Chalk	Chalk with flints about	100	0
	Hard cream-coloured chalk without flints	13	0
Lower Chalk	Yellowish grey marly chalk, soft but enclosing lenticular beds of harder material	1	9
	A variegated marl, upper part usually bluish or yellowish grey, centre dark-grey in places almost black, its base almost invariably greyish buff passing down to	1	4
	A rough nodular layer, nodules parted by green grey marl; this bed also graduates into the chalk beneath — 8 in. to	1	0

Mr. Hill's section is continued at a point on the south side of the line between 300 and 400 yards west of the last position :—

		Ft.	In.
The Grey Chalk	Whitish chalk, weathering in platy pieces, apparently in courses divided by marl bands; all rather hard	23	0
	Hard whitish chalk passing down rapidly into greyish with a marked grey marly band at base (fossils)	1	3
	Hard whitish chalk, weathering into rough platy fragments divided into courses by marked marl-bands	6	0
	Softer marly chalk, rather nodular, bedding indefinite, stained a bright pink	4	0
	Whitish rough hard chalk, in courses	3	0
"The Grey Bed"	Hard grey nodular chalk, becoming platy below; green-coated nodules at base (fossils)	1	6

The section is continued near Weedly Springs, the next 8 feet at the east end of the short tunnel and the remainder on the north side of the line 200 yards east of the signal box :—

		Ft.	In.
Chalk Marl	Hard whitish chalk, rather rough about	20	0
	Hard grey chalk, more gritty at its base, divided into courses by marl-bands	10	0
	Bed of compact limestone, yellowish white rather obscure and broken	1	0
Red Chalk		6	9

This section, as Mr. Hill remarks, shows a complete continuation of the Lincolnshire facies thus far north of the Humber. It is interesting as exhibiting a band of pink chalk in the same position as the lower of the two pink beds at Louth, although no such coloured band has been seen within the limits of Sheet 86. Mr. Hill says: "the sponge bed" seemed to me to be present but with no distinct parting between it and the red chalk. Above it grey and gritty chalk, the equivalent of the "Inoceramus Bed" passes up gradually into the hard and whiter chalk marl . . . . Large Ammonites are common as usual at or just above the horizon of the "Grey Bed."

The following is a list of the fossils obtained by Mr. Hill from the South Cave cuttings:—

	Chalk Marl.	Grey Bed.	Grey Chalk.
Serpula antiquata, *Sow.*	×	×	
Discoidea cylindrica, *Lam.*	×	×	×
Holaster subglobosus, *Leske.*	×	—	×
Terebratulina gracilis, *Schoth.*	×	×	
Terebratula semiglobosa, *Sow.*	×	×	×
„ biplicata, *Sow.*	×	×	
Kingena lima, *Defr.*	×		
Ostrea vesicularis, *Lam.*	×	×	
Plicatula inflata, *Sow.*	—	×	
Pecten orbicularis, *Sow.*	—	×	
Lima echinata, *Etk.*	—	?	
„ globosa, *Sow.*	—	×	
Inoceramus latus, *Mant.*	×	×	×
Spondylus striatus, *Sow.*	—	—	×
Belemnitella sp.	—	×	
Turrilites tuberculatus? *Bosc.*	×		
Ammonites rothomagensis, *D'Orb.*	×	×	
„ sp. (large)	—	—	×
Glyphæa cretacea, *M. Coy.*	×	—	
Fish-teeth	—	×	

Inliers.

The two inliers of Red Chalk and Neocomian have already been mentioned, and the Lower Chalk is of course exposed along the slopes of the deep valleys in which they occur. It is also found in the Cabourn Valley, a branch of the Rothwell and Swallow inlier, though the northerly inclination of the base line of the Chalk carries the Red Chalk below the bottom of the valley. The exposures observed in these inliers are few and small.

At Croxby there is a pit in the Grey Chalk on the east side of the valley, but no good section is exposed.

In the road cutting south of the farmstead one mile east-north-east of Rothwell I found yellowish chalk with *Discoidea cylindrica* and traces of the grey shale band (No. 5).

THE MIDDLE CHALK.

The Middle Chalk of Lincolnshire and Yorkshire has a very different aspect from that of the south of England, but it appears to possess representatives of the same zonal divisions. Lithologically it is divisible into two very unequal parts, the lowest consisting of yellowish shelly chalk without flints (the zone of *Rhynchonella Cuvieri*) and the upper of white compact Chalk with numerous layers of flints (zones of *Terebratulina gracilis* and

Holaster planus). The former is only from 13 to 15 feet thick, the latter is at least 150 feet and probably much more.*

Zone of Rhynch. Cuvieri.—In Lincolnshire the marls which form the top of the Lower Chalk are succeeded by hard yellowish Chalk in massive beds with shaly partings; these are full of fragments of Inoceramus shell and specimens of *Inoceramus mytiloides* and of *Rhynchonella Cuvieri* are common. It was pointed out in the Explanation of Sheet 84 (1884), that this rocky Chalk was probably the condensed equivalent of the Melbourn Rock and the overlying shelly Chalk which in Cambridgeshire are from 50 to 60 feet thick and make up the zone of *Rhynch. Cuvieri*. Mr. W. Hill has recently expressed his concurrence in this view.†

A.J.J.-B.

Mr. Reid furnishes the following description of the Chalk with Flints:—

Nearly a third of the area of Sheet 86 is occupied by Chalk with Flints, which forms the greater part of the Yorkshire and Lincolnshire Wolds, and also underlies the Boulder Clay plain to the east. Probably the flintless Upper Chalk is represented in the district east of Hull, and may also extend a short distance into Lincolnshire; but there are no sections of it visible at the surface.

The Chalk with Flints consists of hard white Chalk, in the lower part thick-bedded, but becoming markedly stratified, or even flaggy, in the upper part. Partings of grey clay occur abundantly. Near the base the flints are in small scattered irregular nodules, often with a black centre, but more usually grey throughout. These nodules are often embedded in a layer of hard, white chalk, which is closely united to the flints, and is divided by joints or cracks which cut through chalk and flints alike, so that the latter are severed like pebbles in a cleaved conglomerate. Occasionally the nodules are pinkish, but neither the large black nor the red flints found in the Boulder Clay, appear to occur in place in this district. Upwards the proportion of flint becomes gradually greater, and the scattered nodules form regular lines. Then the flints are found closer together, often forming large flattened masses or floors several yards across, and thin seams of tabular flint are abundant, both in the planes of bedding and in joints. In the higher portion the flints are curiously interbedded with, or penetrated horizontally by chalk, and send tongues into the chalk. Their surfaces are also often honeycombed in a very peculiar way, for on this horizon instead of forming nodules, or solid masses, the flint tends to ramify in spongy, imperfectly formed masses along the bedding planes of the chalk. Fossils are very scarce, *Inoceramus Cuvieri* and *I. Brongniarti* being the only species noticed within this Map.

C. R.

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* The broken line engraved upon the Map is the division between the Chalk with flints and that without flints; it does not therefore represent the actual base of the Middle Chalk, but runs about 14 feet above it.

† *Quart. Journ. Geol. Soc.*, vol. xliv., pp. 330-364.

Mr. Jukes-Browne contributes the following notes on the Middle Chalk:—

Zone of Rhynchonella Cuvieri.

The most southerly point on the main outcrop where these beds were observed was in the quarry south-east of Caistor, near the old windmill, which shows the whole of this zone and its junction with the chalk above:—

	Feet.
Soil and rubble	3
Hard white chalk with two lines of flints	6
Shale and shaly chalk	0¼
Hard greyish chalk in beds about one foot thick with partings of grey shale	11
Soft grey shale (seen at one place).	
About	20¼

The shale partings in the lower part are 4 to 6 inches thick and contain rounded nodular lumps of hard yellowish chalk. Fragments of *Inocerami* are abundant in this grey chalk. A similar section is visible in the quarry a quarter of a mile east-north-east of the Church.

A. J. J.-B.

The following notes on sections north of Caistor are by Mr. Fox-Strangways who surveyed that portion of the outcrop:—

In Elsham Church Wood a quarry, about 40 feet deep, shows the lower flintless beds of the Middle Chalk and some thickness of the flinty chalk above.

At the upper cross roads near Horkstow a pit exposes a similar section the upper beds consisting of white chalk with bands of nodular flint, weathered and splitting up vertically; the lower beds of which about 6 feet are exposed are thick-bedded, with a marked (shaly) band at the junction. The beds dip at about 13° towards the scarp.

At South Ferriby north-east of the Church this junction is again exposed in a chalk pit, the whole of the zone of *Rhynch. Cuvieri* being seen, together with some of the underlying Grey Chalk, including the soft shaly band (No. 6); this is much broken and disturbed, probably from slipping, the quarry being just at the north-west angle of the Wolds. C. F. S.

The following notes are by Mr. Jukes-Browne:—

Passing over the Humber a fine section is to be seen in the large quarries west of Hessle station; I visited these in company with Mr. Strangways in 1880, and took the following notes of the section then exposed:—

	Ft.	In.
Chalk rubble	2	0
Pure white chalk, rather hard, with a layer of large nodular grey flints	6	0
Continuous layer of greyish-white flint stained yellowish by iron in places	0	4
Hard and tough semicrystalline limestone, tinged with yellow (like Chalk Rock)	2	0
Soft chalk with horizontal strings of grey marl	0	9
Massive white chalk without flints	3	0
The same with large flints near the base	3	0
Thin layer of clay.		
White chalk with flint nodules	2	0
Thin layer of clay.		
White chalk with flints of irregular elongate shape and *Inoceramus Brongniarti*	6	0

	Ft.	In.
Layer of dark clay	0	2
White chalk, in courses of from 2 to 3 feet thick, without flints (*Inoceramus mytiloides*)	26	0
Rough yellowish chalk (with *Inoc. mytiloides*) seen in pits below the level of the rails	10	0
Total	61	3

I took the chalk which is seen below the level of the line to be that which is usually found above the zone of *Bel. plena*, but the succeeding beds are different from any seen elsewhere, and it would seem as if the sharp demarcation which prevails in Lincolnshire (and again at South Cave) between the zone of *Rhynch. Cuvieri* and that of *Terebratulina gracilis* were here bridged over by the local occurrence of passage beds.

Dr. Barrois thought a representative of the still higher zone of *Holaster planus* exists here, but I saw no evidence to support this idea; on the contrary I should imagine that barely half the zone of *Ter. gracilis* was here shown. He was, however, the first to identify the occurrence of the lower zones here.*

In 1878 Rev. J. F. Blake gave some account of the quarry, from which the following is extracted†: "There are three distinct bands in it, known to the workman and quarried for different purposes. The lowest bed‡ is worked for whiting as it is entirely free from flints, except thin layers between the great beds. It is this that produces the great number of shark's teeth (*Ptychodus mammillaris*) for which the quarry is noted and it also contains *Inoceramus Cuvieri* [? *mytiloides*]. Next above this is the "road stone" only used for that purpose on account of the nodular flints which it contains; its fossils as noted by me are *Terebratulina gracilis* and *Echinoconus subrotundus* and others are noted by Dr. Barrois. The top is the "limestone" which is burnt. This has flints in bands but at wide intervals. . . . It is overlaid some height further up by the chalk with thick-bedded flints to be noticed hereafter."

The next good section of the lower part of the Middle Chalk is in the railways cutting near Sugar Loaf Hill, east of South Cave and just outside the northern edge of Sheet 86. The beds here differ from those just described, but are similar to the Lincolnshire type. Between the lowest layer of flints and the laminated grey marl (zone of *Bel. plena*, see p. 118) there are 13 feet of "hard rough cream-coloured chalk weathering into platy pieces with rough surfaces, divided into courses not less than a foot thick by bands of yellowish-grey marl."§

Inliers.

The outcrop of the zone of *Rhynch. Cuvieri* can of course be followed round the three inliers in the southern part of the sheet, and the broken line engraved on the Map is the boundary line between it and the overlying chalk with flints. Exposures were observed in each of these inliers:—

1. *Thoresway and Croxby Inlier.*—There is a pit by the side of the road a quarter of a mile north of Thoresway Church, showing, in the upper part, friable white chalk, broken into small blocks by vertical joints, and in the lower part hard thick-bedded chalk with irregular layers of grey shale. Between these levels there is talus, but no flints were seen, and the whole may belong to the Chalk without flints.

* Recherches sur le Terrain Crétacé Supérieur de l'Angleterre et de l'Irlande, 1876; p. 189.
† Proc. Geol. Assoc., vol. v., p. 252.
‡ That is, the lowest bed above the level of the rails in the main quarry.
§ W. Hill, *Quart. Journ. Geol. Soc.*, vol. 44, p. 339.

2. *Rothwell Inlier.*—The junction of the flint-bearing and flintless Chalk is exposed in a pit half a mile south-east of Rothwell, the section here being as follows:—

	Feet.
Soil and rubble	3
Hard white chalk, with courses containing embedded grey flints	10
Nodular chalk and grey shale, in thin layers	0½
Hard greyish chalk in thick beds	10

Small specimens of *Rhynchonella Cuvieri* occur in the shaly beds. There is a slight inclination to the north-east.

Another pit, some 6 furlongs west-north-west of Rothwell, also shows these hard rocky beds which underlie the Chalk with flints; they are separated by layers of buff-coloured marly shale, 4 to 6 inches thick, and containing loose nodules or lumps of chalk. In the hard beds here, I found a small Ammonite, badly preserved, but resembling *Am. prosperianus;* broken shells of *Inoceramus* were also abundant.

3. *Cabourn and Swallow Valley.*—The greyish rocky beds are seen in the floor of the pit half a mile south-east of Cabourn Church; but a better section is exposed in a pit on the south side of the road a mile east of Cabourn, as follows;—

	Feet.
Soil and rubble	4
White chalk with flint nodules	1½
Hard rough chalk, with layers of grey shale	0½
Hard greyish white chalk, gritty, with fragments of *Inoceramus*, in thick beds	8

The junction line here is at a higher level than the continuation of the feature would indicate, as if it were thrown up by a small fault.

The same beds are again seen in a pit on the north side of the road west of Swallow; about 6 feet of them are exposed with a shaly bed at the top, overlaid by the white chalk with flints, of which there are 10 or 12 feet.

Besides the pits already mentioned where the base of the Chalk with Flints is exposed, these beds may be seen at the following places:—

Thoresway.—A pit 5 furlongs south-east of the Church.

Rothwell.—Pits half a mile west, half a mile north-north-west, and one mile north-east of the Church.

Cabourn.—A pit half a mile south-east of the Church.

Cuxwold.—A pit a quarter of a mile south-east of the Church.

Croxby Pond, by the roadside east of the Lake. This shows two thin seams of grey clay. Another pit half a mile north-east of the Pond shows about 20 feet of hard white chalk with layers of flint, nearly continuous, but thinning and thickening lenticularly; one of these averages 5 to 6 inches in thickness, and does not split conchoidally but rectangularly.

Hatcliffe.—A pit half a mile north-east of the Manor House Farm. The floor of this pit is a continuous layer of flint; in the chalk above there are several thin horizontal layers of flint and four layers of lenticular flints, one of which, about 5 feet from the top, includes interlaminated layers of chalk. Another pit, nearly half a mile south-east of Hatcliffe, shows similar chalk with lines of large lenticular flints, and one continuous layer of grey flint 6 to 8 inches thick; there is also a thin seam of grey marly clay.

West Ravendale.—An excellent section of this part of the Chalk is seen in a chalk pit by the roadside at this place showing :—

	Ft.	In.	
Chalk with large nodules and discontinuous layers of flint	18	0	
Continuous layer of flint and chalk, interlaminated	0	6	to 8 in.
Massive chalk without flints	3	6	
Layer of grey marly clay	0	3	to 4 in.
Chalk with scattered flint nodules	6	0	
Continuous layer of solid flint	0	6	
Chalk with large nodules and discontinuous layers of flint	22	0	
	51		

Another quarry, south-east of the above, shows the same series, and there are old workings all along the steep slope of chalk, which forms the north-east side of the valley.

The same Chalk with flints can be seen in pits half a mile south-west and 5 furlongs north-north-east of East Ravendale.

In a pit 3 furlongs north-north-east of Wold Newton some very large Paramoudra-like flints occur, the section being like that at Ravendale.

Another pit, 5 furlongs south-south-east of Wold Newton, shows about 25 feet of Chalk, with layers of flint about 2 feet apart, and scattered nodules of flint between these layers.

A. J. J.-B.

Mr. Reid continues the descriptions as follows:—

Hawerby.—A pit behind the farm buildings half a mile north-west of Hawerby Church shows well-bedded, flaggy-looking Chalk, with beds of tabular flint. Dip not obtainable, but apparently small.

East Ravendale.—A pit three-quarters of a mile north of the village shows 30 feet of Chalk with many layers of tabular grey flints; a seam of marl an inch thick occurs low down in it.

The tabular flints in the sections in this neighbourhood are generally imperfect, containing tongues of Chalk. Some of the layers are nodular, but irregular-shaped nodules are comparatively rare.

East Ravendale Field (due east of).—An old pit shows bedded Chalk with tabular flints.

At Swallow Vale there is a pit showing Chalk, with scattered nodular flints.

At Swallow a pit 10 chains east of the Church exposes Chalk, with flint nodules.

Audleby Top Cover, near Clixby.—In a pit Chalk, with scattered flint nodules, is exposed. The dip is north-north-east.

Irby Church (half a mile south-east of).—Thin-bedded Chalk, with irregular layers of tabular flints, is exposed in a pit; dip not obtainable.

Irby.—In a pit a quarter of a mile south-west of the Church Chalk, with floors of flint or tabular flints, and some decayed pyrites, is exposed.

Irby.—Pits a quarter of a mile north-west of the Church show Chalk with nodular and tabular flints and a seam of marl. Two vertical joints are filled with flint. The direction and amount of dip are uncertain.

At Aylesby Washing Dales there is a pit in flaggy Chalk with continuous floors of flint.

Riby Church (half a mile south-east of).—A pit shows a section of Chalk with many layers of tabular or flattened nodular flints (14 lines in 30 feet).

Riby.—In a pit one mile south-south-west of the Church, Chalk, with flint floors and thin tabular flints, is exposed. The bedding is horizontal.

Riby (half a mile south-west of).—A pit shows Chalk with marl partings and layers of flat or nodular flints.

Riby Church (half a mile west of).—There is a pit in hard Chalk; the flints more nodular than in any of the sections previously noted; at one point a nearly vertical joint is filled with flint. Fragments of a large *Inoceramus* are common.

Keelby (half of a mile south-south-east of).—A pit furnishes an exposure of Chalk with flints. The dip to the north-east is very slight. The Chalk at the bottom of this pit shows open fissures, through which the water rises after wet weather or in winter.

Keelby (a quarter of a mile south of).—Chalk, with nodular flints, imperfect flints, and floors of flint, is exposed in a pit.

Brocklesby (half a mile south of).—A pit shows Chalk with floors of flint and large nodules. Dip about east-north-east.

Limber (half a mile east-south-east of).—Chalk with imperfect and flattened flints is exposed in a pit.

Limber.—A well at Mr. Frankish's house was sunk entirely in Chalk with layers of flint to a depth of 168 feet.

Limber (one and a quarter miles south-south-west of).—Chalk with many layers of flat and tabular flints is exposed in a pit. The beds are horizontal.

Limber.—A pit one and a half miles west-south-west of the Church shows Chalk with many layers of imperfect flints.

Limber.—In a pit in the village, a quarter of a mile west of the Church, Chalk with tabular or flat flints is exposed.

Limber Parva.—A pit (with lime-kiln) affords a section of Chalk with floors of flint and a few partings of marl. The dip is north-east. The depth exposed is 40 feet.

Somerby Dolter (north of).—There is a pit in Chalk with nodular pinkish flints.

Kirmington.—A pit half a mile south-east of the Church exposes Chalk with nearly continuous layers of flattened flints.

Kirmington Vale, Chalk with a few scattered flint nodules.

Ulceby (south of).—A large pit, 28 feet in depth, exposes Chalk with layers of nodular flints, a few thin seams of tabular flint, and two or three partings of marl. The Chalk is quite horizontal and undisturbed, except by step faults, none of which let down more than 8 inches.

Ulceby (by the roadside, one mile west of).—There is a pit in Chalk with many continuous regular layers of imperfect flints and a few lines of nodules. At one spot, near the bottom of the pit, there is an enormous flint nodule, which bends the beds as though it were a boulder dropped from above. The dip is due east at 1°. The thickness exposed is 30 feet.

Wootton.—A pit, west of the Hall, shows 25 feet of Chalk with many lines of imperfect tabular flint and flattened flints, and partings of marl. Two or three small faults are seen, none more than a few inches; as usual in this district, the downthrow is against the dip. The beds dip E. 25° N., at an angle of 2°.

Wootton.—An old pit near the tumulus at How Hill is in Chalk with a layer of large flattened or tabular flints.

Wootton.—A pit near Dunkirk exposes Chalk with tabular flints and large nodules. On one horizon there are a number of large *Inoceramus*. The beds dip east-south-east at 1°.

Croxton.—North of Parsonage Farm, there is a small pit, in Chalk with layers of flattened nodular flints, often containing parts of a large species of *Inoceramus*; there are two or three partings of marl.

Croxton.—A pit a quarter of a mile north-west of the Church, exposes 15 feet of Chalk, with a layer of large grey flints, a few nodules, a mass filling a vertical joint, and one marl parting. The dip is probably due east.

Thornton Curtis.—In a pit due north of the Church Chalk with nearly continuous beds of flint, and containing marl seams in the lower part, is exposed.

Thornton.—A pit three-quarters of a mile due west of the Church shows Chalk with many layers of flattened and tabular flints. The beds dip about N. 10° E. at an angle of 1°. A small fault with downthrow to the south is visible.

Thornton Curtis (north-west of).—There is a pit in Chalk with large flints passing into tabular masses.

Burnham (three-quarters of a mile east of).—20 feet of Chalk is exposed in a pit. The section consists of Chalk with many layers of large flat or

tabular flints one tabular flint being only 1 inch thick but several yards long. A few nodular flints are nearly black, but all the others are grey. Near the top of the section there is a marl seam 3 inches thick, and at the base a marl parting. Fossils are rare, the most common being fragments of a sulcated *Inoceramus*. The beds dip E. 30 N., at an angle of 1°.

Burnham.—There is a pit three-quarters of a mile east of the Plantation, in Chalk with many layers of flint, occasionally tabular, and several marl partings. Several small step faults are visible. The beds dip E. 20° S., at an angle of about 4°, but both direction and amount of dip are rather uncertain.

Burnham (a quarter of a mile south of).—A pit shows Chalk with layers of nodular and flattened flints and seams of marl. Flints are not nearly so abundant as in most of the pits in the neighbourhood. The dip appears to be N. 25° E., at an angle of 2°.

Burnham.—There is a pit, at the cross roads north of Burnham Plantation, in thin-bedded Chalk with tabular flints; the flints are very imperfect and irregularly mixed with Chalk. One flint, 2 feet 7 inches high and 2 feet across, was an upright cylinder, but not like a Paramoudra. The dip is southerly but variable.

On the other side of the road, just north of the last section, there is another pit showing a ½-inch seam of marl, and a 1-inch seam of tabular flint over 20 feet long. Both these pits show disturbances, but no definite fault line is traceable, and the direction of the dip is very doubtful.

Melton High Wood (half a mile north of).—Chalk with scattered flint nodules and a 2-inch seam of marl is exposed in a small pit.

Melton Ross, Whiting Works.—A large pit exposes on each side of the rail a thickness of 50 feet of hard rubbly Chalk with occasional seams of marl, and a few scattered nodular flints, some of which are pink. The direction of dip is north-east.

Melton Ross (about half a mile north of).—A pit shows Chalk with scattered pinkish flint nodules and partings of marl, full of joints and small faults. The dip is uncertain.

Elsham.—A pit near Court Close exposes Chalk with scattered nodular flints and a marl parting. The direction of dip is north-east.

Elsham (three-quarters of a mile north of).—A pit shows Chalk with nodular flints, full of open fissures and much shattered. The beds dip in an easterly direction, but the exact direction and amount are not clear.

Elsham (half a mile north of).—There is a pit in Chalk with scattered flint nodules and a few marl partings, much shattered and full of open fissures. The direction of dip is E. 15° N.

Worlaby (one mile north-east of).—Thick-bedded Chalk with scattered flint nodules is exposed in a pit; dip not obtainable.

Saxby Mill (just south of).—A pit shows Chalk with nodular flints. The dip is untrustworthy, as faults, with downthrows to the north, are seen in the pit.

Barrow (south of).—A large pit exposes Chalk with many horizontal layers of flint.

Barrow.—A pit at the cross roads, three-quarters of a mile south-west of the Hall, shows horizontal beds of Chalk with flint nodules and tabular flints.

Barton.—There is a pit, half a mile south-east of Deepdale Farm, in Chalk with layers of flint nodules, one line forming large irregular tabular masses, and a 2-inch seam of grey marl. The beds dip at 2° in a direction S. 20° E.

Barton.—A pit in Deepdale, half a mile west of the farm, shows bedded Chalk with very rare flint nodules. The beds dip N. 25° E. at an angle of 2°.

Barton Wold Farm.—A dip N. 10° W. at 2° was obtained in Chalk with a few flint nodules.

Barton.—There is an old pit, one mile east-south-east of the Church, in Chalk with layers of large flint nodules.

Barton.—A pit half a mile east-north-east of the Lodge exposes bedded Chalk with tabular flints, flint nodules, and partings of marl; one cheese-shaped flint, 20 inches across by 14 inches deep, was noticed.

Barton (one mile south-east of).—An old pit, near the Lodge, affords an exposure of Chalk with many nodular flints.

Barton (near the Mill, south-east of).—Chalk with large flint nodules is exposed in a pit.

Barton.—A pit a quarter of a mile from the village, on the Burrow road, shows Chalk with layers of nodular flints and a 2-inch seam of greenish clay. The dip is S. 10° E., at an angle of 1°.

Barton.—A pit by the high road west-south-west of Kingsforth exhibits Chalk with a few scattered nodular or finger-shaped flints, and a 1-inch seam of greenish marl containing broken up Chalk. The beds dip north-east at about 4°.

Barton.—There is an old pit, half a mile south of Beacon Hill, in Chalk with tabular flints.

Barton.—An old pit, three-quarters of a mile west-north-west of Beacon Hill, shows hard Chalk with a few nodules of grey flint; dip not obtainable.

Barton.—A pit half a mile west-south-west of Hill Farm exposes horizontal beds of Chalk with a few flint nodules.

Barton (west of).—A pit shows 50 feet of Chalk with a few scattered flint nodules throughout. Dip S.S.E. Small faults, with downthrow to the north, are visible.

Barton.—There is a pit, half a mile north-east of Grange Farm, in Chalk with lines of nodular grey flints.

Ferriby Hall (one mile east of).—In a pit near the Farm there is an exposure of Chalk with nodular grey flints; dip not obtainable.

C. R.

CHAPTER XVI.

SUPERFICIAL DEPOSITS.

WEST OF THE WOLDS AND SOUTH OF THE HUMBER.

South of the Humber.

The superficial deposits of the Ancholme and Trent valleys are of such variable composition, and their relations, both as to time and position, so ill-defined by surface indications, that it is not always certain to which of the great classes, Glacial or Post-Glacial, a deposit may belong. The boundaries of the Drifts are also rendered indefinite by the frequent resemblance they exhibit to the solid rocks on which they rest, as in the case of the sands on the Kellaways Rock Sand, and the Chalky Boulder Clay, and Clay at a lower level on the Lias, Oxford, or Kimeridge Clays.

The Chalky Boulder Clay is the oldest known glacial accumulation in the area, it occurs in the districts composed of the Oxford and Kimeridge Clays, and covers a considerable part of the Liassic area; but upon the Oolitic escarpment, and on its dip-slope rising westward from the Ancholme valley, it is absent. The Chalky Boulder Clay caps the higher grounds, having been deposited upon a surface through which the Ancholme and its larger tributary valleys have since been cut.

Although where typically developed this Boulder Clay is crowded with Chalk fragments, it is variable in character, and is often without Chalk in districts remote from the Wolds.

Upon the Chalky Boulder Clay patches of Gravel, usually much current-bedded, occur here and there, notably on Wrawby Hill; organic remains have not as yet been found in them.

Similar gravels occur in patches, at various heights above the Alluvium of the Trent, on the Liassic rocks in districts where there is no Boulder Clay; they are usually composed of local materials so arranged as to suggest conditions somewhat analogous to those which produced the Eskers.

These gravels appear to be of different ages, they may be the relics of a denudation extending intermittently from early Glacial to newer Glacial, and perhaps even to early Post-Glacial, times.

There are four small patches of Gravel composed of Oolitic materials upon the very summit of the Oolitic escarpment, a position which, coupled with their isolated and fragmentary condition, would indicate a relatively greater antiquity than that assigned to the other gravels; and would possibly refer them to a period anterior to the Chalky Boulder Clay.

The Gravels of Hardwick Hill and some other places show a distinct derivation from the Chalky Boulder Clay.

The excavation of the Ancholme valley through the Chalky Boulder Clay resulted in the accumulation of a series of sands and

gravels associated with red-brown grey-veined Clay, which is regarded by Mr. Jukes-Browne as Newer Glacial.

In the Ancholme valley bottom this Clay is usually thin, and apparently impersistent in the sand and gravel.

In places, as in Little Carr Drain, the Clay is evenly laminated and indistinguishable in character from the ancient Warp of the Humber between Barton and South Ferriby. There are, however, tracts of rising ground on the flanks of the Ancholme valley, as, north of Wrawby, at Winterton Holme and Winterton, where the Clay contains chalk pellets, and must be regarded as a true Boulder Clay.

Although there is no reason to doubt the contemporaneous origin of this Boulder Clay and the stoneless and laminated Clay, it is manifestly impossible to tell whether the overlying sands and gravels are referable in part or altogether to Post-Glacial deposition; so that except where the Clay is of sufficient superficial extent to be mapped separately, we include it with the sand and gravel under the general term "Low level deposits of the Ancholme valley." These deposits are, as a rule, separated from the Chalky Boulder Clay, by a slope formed of Oxford Clay.

The section in the low cliff near South Ferriby seems to establish a distinct connexion between the stoneless clay and the true Boulder Clay, and shows that both were accumulated subsequently to the formation of the indurated gravel and sand bed on that shore which may belong to the Raised Beach period.

There is a strong probability that the Low level deposits of the Ancholme valley are represented by laminated clays, sands, and gravels in the Alluvial districts forming the western portion of Sheet 86.

The undoubtedly Post-Glacial deposits in this Sheet, consist of Peat, Warp and Blown Sand. Where the Blown Sands rest upon deposits of sand and gravel from which they have been derived, as in the districts between Elsham and the Humber and between Brigg and Barnetby, and in parts of the Trent valley, it is impossible to distinguish them by definite boundaries.

The Superficial Deposits on the west of the Wolds will be described under the following heads, or sections:—

Chalky Boulder Clay.
Old Gravels.
Low-level deposits of the Ancholme Valley and Brown Boulder Clay.
Sand, Peat and Alluvium of the Trent Valley.
Peat and Alluvial deposits of the Ancholme Valley.
Blown Sand.

The Blown Sands are confined to the area west of the Wolds. Much of this Sand may have been drifted prior to and during the accumulation of the Peat and Alluvial deposits mentioned in the two preceding sections, and considerations as to derivation might entitle it to a prior position, but as, in many tracts, the Sand is shifting now, it has been given last.

Geographically the deposits on the west of the Wolds naturally fall into two groups, those of the Ancholme Valley and those of the Trent Valley.

The occurrence of marine sands between two Boulder Clays in the area on the east of the Wolds, prevents an absolute correlation of the drifts on that side with those on the west of the Wolds, and calls for a separate description, which is furnished by Mr. Reid, who surveyed that district.

Chalky Boulder Clay.

The Chalky Boulder Clay, where typically developed in the vicinity of the Ancholme and Trent valleys, consists of bluish-grey clay, weathering pale brown, containing numerous fragments of chalk and flint, and occasionally of foreign grits and of quartz.

In the Ancholme district the Chalky Boulder Clay is confined to the area south of Elsham Station (on the Barnetby and Doncaster Line), between the Ancholme Alluvium on the west, and the Barnetby, Louth, and Lincoln Line on the east. In this district it caps the higher ground of the Oxford and Kimeridge Clays.

In the Trent district Chalky Boulder Clay caps the highest part of the Liassic area in the south part of Sheet 86, between Blyton, Scotterwood, and Messingham, and the Oolitic escarpment. On its western margin the Boulder Clay obscures the junction of the Lias and Rhætic beds.

From Messingham northward to the Humber, one small patch of Boulder Clay on the northern slope of the valley east of Flixborough, by the road between Frodingham and Burton, forms the sole direct evidence of glacial action. Whether it indicates the northerly extension of the Chalky Boulder Clay over the Liassic area to the Humber, or is of more recent formation there is no means of proving.

(*a.*) *Ancholme District.*

The ramification of valleys which intersect the Oxford and Kimeridge Clay districts, south of Elsham Station, as they have in most cases been cut through the Drift to the solid rock, interferes with the continuous extension of the Chalky Boulder Clay, cutting it up into a series of isolated patches.

Prolonged from Sheet 83, on the south, the most westerly patch of Boulder Clay on the margin of the Ancholme Alluvium occurs at Gullham Farm, between which place and Claxby Moor there are two other patches. At Gullham the Chalky Boulder Clay is at a rather low level, being bounded on the west and north-west by sands which overlie the Low-level Clays of the Ancholme valley, or form a wind-drift derived from them.

About Thorton-le-Moor, South Kelsey and North Kelsey the boundaries of the Boulder Clay patches occur high up on the slopes.

The Thornton-le-Moor patch extends from a little west of that village nearly as far eastward as Holton-le-Moor; as in the other patches, there is abundant evidence of the characteristic Chalky Clay.

The South Kelsey patch terminates at Winghall farmyard, where it is separated by a narrow band of Oxford Clay from gravel and clay of the Low-level series, which here occurs rather high upon the slope.

Rainwash, producing a scattering of Boulder Clay *débris* down the slopes, obscures the signs of the Oxford Clay, where the ditches are not deep on the western slope from the South Kelsey patch to the Ancholme Alluvium; and the same remark applies to the other parts of the Oxford Clay district and to the area occupied by Kimeridge Clay south of Barnetby.

At Decoy House the large North Kelsey patch of Chalky Boulder Clay is separated by about 2 chains' width of Oxford Clay, on the slope, from sand, which is probably connected with the Low-level deposits of the Ancholme Valley. Similar sands separated by wider belts of Oxford Clay from the Chalky Boulder Clay on the hill tops occur at and to the north of Ings House.

Between Gadney and Kelsey New Mill the Oxford Clay is exposed in a pit in which it is capped by 5 feet of Gravel, forming the base of the Chalky Boulder Clay.

West of North Kelsey the Boulder Clay of Gadney may be continuous with the main mass as shown on the Map, but the ridge is slightly lower for 10 or 12 chains, suggesting the probability of its insulation.

From the gravel patch at Cadney, which overlies its western termination, to Howsham, and from Howsham northward to Howsham Barf, Chalky Boulder Clay covers the higher gound; it is characteristic Chalky Clay.

North of the road to Howsham, at three-quarters of a mile from Cadney, three large boulders of siliceous grit are visible on the slope, one of them being nearly 5 feet in length. Although some distance below the boundary of the Chalky Boulder Clay they have evidently come from it. A similar boulder occurs in Cadney, at the turning to Brigg.

The slope below the Chalky Boulder Clay north-east of Cadney is broken by a small hill-feature capped by gravelly loam which is probably the relic of an outlying patch of Boulder Clay denuded.

The most northerly patch of Chalky Boulder Clay in this district lies on the spur of high ground between Elsham, Barnetby, and Brigg; it is for the most part overlain by the Gravel of Wrawby Hill, which also conceals its junction with the Oxford Clay on the east of Wrawby; it emerges from beneath the gravel in the north part of Wrawby, and has been quarried for gravel on the north-west of the village where the included fragments are remarkably numerous. The Chalky Boulder Clay (pale brown clay with numerous chalk and flint pebbles) is also exposed in the stream west of Wrawby Church at 12 chains from the high road. Oxford Clay is visible at about 7 chains from the high road. On the west of Wrawby the Chalky Boulder Clay is separated from the Low-level Ancholme Valley Clay and its associated deposits by narrow bands of Oxford Clay.

Proceeding from Wrawby toward Brigg the boundaries of the Gravel and underlying Chalky Boulder Clay soon become conterminous. South of Wrawby Mill the Chalky Clay emerges from the Gravel, extending thence southward on the projecting hill cut through by the Railway, between Brigg and Barnetby. In this cutting the Oxford Clay is overlain by 5 feet of brown and grey clay with small worn flints and pellets of Chalk.

In draining the hill, on the south side of the Railway, the clay was found to be full of Chalk fragments, which, when not mashed up in it, are well worn and often striated. In some of the drains a spit of buff sand and gravel was cut through, in the Boulder Clay. Beneath about 4 feet of this Boulder Clay and gravel Oxford Clay was exposed on the slopes separating the Chalky Boulder Clay from Low-level Ancholme Valley Clay, exposed at 3 chains below it, north of the letters *igg* in the words Glamford Br*igg*s on the Map; Oxford Clay forms the slope for 2 chains, separating the Chalky Boulder Clay from the sands of the Low-level Clay series on the east.

The Chalky Boulder Clay seems to be overlain by the Low-level Clay, or there intervenes a strip of Oxford Clay too narrow to be detected, about Gorse Cover, east of Brigg. The exposures furnished by a ditch bounding

what used to be called Gorse Cover proceeding down the hill are as follows :—

For 2 chains from the summit, sand, grey and brown mottled clay resembling the Low-level Clay.
For 4 chains sand and gravelly soil.
Chalky Boulder Clay.
At two chains further unctuous grey clay (? Oxford Clay).
The Low-level Clay has been got out of the ditch further down.

North of Elsham Station there is no land on the flanks of the Wolds of sufficient altitude to show the Chalky Boulder Clay, and on the Lincolnshire Limestone, on the west of the Ancholme Alluvium, it is never found.

The gravelly nature of the Chalky Boulder Clay, near Wrawby, and in the drains south of the Railway cutting between Brigg and Barnetby, may explain the 5 feet of gravel representing the base of the Chalky Boulder Clay between Gadney and Kelsey New Mill, and shows that some care is necessary in distinguishing between a gravelly soil or thin patch of Chalky Boulder Clay and a *bonâ fide* gravel underlying it.

(*b.*) *Trent District.*

The main mass of the Chalky Boulder Clay extends from Scotterwood Farm southward into Sheet 83; it is for the most part concealed by Blown Sand upon Scotton Common, but on the south of the Common and upon the slope extending from Scotterwood to Laughton Wood it forms the surface. In this tract the Boulder Clay is by no means uniform in composition.

Between Southorpe and Blyton the prevalent colour of the Clay is drab and pale brown; it contains broken flints and, in places, pebbles of hard Chalk, saccharoid grit and quartz; the western margin of the Boulder Clay, near Southorpe, is loamy. Near Northorpe the Boulder Clay contains pebbles of flint, quartz, and saccharoid grit. At about half way between Blyton and Northorpe stones are sparsely disseminated in the Clay.

Near Scotton Field characteristic Chalky Boulder Clay is exposed in the ditches.

In Scotton Common the limit of the Boulder Clay under the Sand does not appear to come east of the letters *mm* in the words Scotton Co*mm*on on the Map.

Bluish-grey Boulder Clay, with bits of flint and foreign fragments, often jaspideous, was exposed in draining by the road near the Scotter end of Scotton Common.

The slope south-west from Scotterwood is composed of Boulder Clay, which has been worked in several pits, apparently for the gravel furnished by its contained fragments.

At half a mile south-west of Scotterwood a pit on the slope shows drab and brown Clay, marbled with bluish-grey veins, containing worn fragments of white flint and Chalk, and, less frequently, pieces of Lias limestone and shale, white saccharoid grit, and of other grits. One fragment of purplish porphyritic rock was obtained.

In a pit near Scotterwood, on the west, the Boulder Clay is exposed to a depth of from 10 to 15 feet; it seems to be made up of Lias, Rhætic and Keuper materials, and contains worn fragments of flint, Lias limestones and, occasionally, foreign grits. The floor of the pit appears to be Lias.

At the bend in Scotton Common Fence, north-west of Laughton Wood, the ditch shows 4 feet of reddish-brown clay, loamy toward the surface; containing pebbles and angular fragments of flint, Chalk, foreign grits and Lias limestone. The sandy soil of the Common has probably been blown over the surface from the west and north; it appears to be very thin in places, as yellow clay has been turned out in one spot by the road to Hardwick Hill.

In the village of Laughton two large boulders are visible. The smaller one stands by a farmhouse near the Church; it is composed of grey fossiliferous rock resembling quartzite. The larger boulder stands in front of the Blacksmith's shop in the lower (westernmost) part of the village. It had been moved with great labour from the old site of the shop, some years ago. This boulder is 5 feet × 4 feet × from 2 to 3 feet in greatest dimension. It is composed of very hard greenish-grey rock, weathering brown (? metamorphic). This boulder bears a date 1766, probably the date of removal from the Boulder Clay area or its outskirts. 32½ c. is also inscribed on it; if meant for weight it is a great mistake through omitting the multiplication by 3rd dimension.

A considerable stretch of flat ground, with brown loamy soil with pieces of flint, occurs on the south-east of Northorpe Station; it appears to be the Alluvium of the tributaries of the River Eau, probably formed of *débris* from the Boulder Clay upon the surrounding hills. Flanking this plain both on the north and south there are narrow tracts of gently rising land composed of sandy detritus, which may be the result of atmospheric denudation, as there is apparently no deposit in this district corresponding to the Low-level Clay of the Ancholme Valley. Above these gentle slopes the Oxford Clay forms the hill sides, and is capped by the Chalky Boulder Clay of Scotland Farm and by a patch further east (both prolonged from Sheet 83 on the south); also by a patch of Boulder Clay extending from Grayingham westward toward Northorpe Station and toward Fox Cover, east of Northorpe. Seven feet of Boulder Clay (brown clay with fragments of flint) rests on the Lias in the Railway cutting north-east of Northorpe Station. The Grayingham patch is very loamy in places, which may be partly accounted for by the ferruginous Liassic beds which it conceals.

On the south-west of Kirton Lindsey a patch of Boulder Clay, chiefly composed of grey clay with flint fragments, caps the high ground; it is cut through by the Railway; near this patch, on the south-east, is a smaller hill-capping of Boulder Clay.

Between Kirton Lindsey and Manton Warren there are two patches of grey flinty Boulder Clay with occasional old rock fragments; the larger patch is about a mile west of Mount Pleasant; the smaller, at less than a mile west of Cleatham. In the dispersion of foreign fragments in the soils of the sandy and loamy districts about Messingham, we have some indication of the former extension of the Boulder Clay; and in the valleys between Grayingham and Cleatham tumulus, sandy deposits occur, in which traces of partial derivation from the Boulder Clay are apparent.

By the road to Scotton Wood, proceeding up the gentle slope from the stream on the east, a freshly cleaned ditch showed sand with grey clay near the stream, giving place higher up to loam and clay with occasional worn grit fragments of fair size, upon bluish clay with Lias fossils (either a Boulder Clay made up of Lias materials kneaded up, or Lias *in situ*). A cross drain on the north of the road showed similar clay with broken fragments of Lias limestone, interspersed in places with bits of flint and quartz. Just about here the soils are very variable. A farmer, Mr. Pycock, of East Carr Farm (small farm by turning in direction of Rannelow), tells me that he sunk through the following beds before reaching rock in a well at his house:—

Loamy soil, about 18 inches.
Grey sand, about 18 inches.
Clay with occasional stones, 3 feet.

The last-named may be Boulder Clay; he tells me that it is very irregularly covered by sand, and frequently comes to the surface. No reliance can be placed on soils by hedges, as Mr. Pycock informed me that it is customary to bank up the hedges with the best soil procurable in their vicinity to promote their rapid growth.

North of the letter *a* in the word Rannelow Boulder Clay, at least 3 feet thick, seems to form an inlying patch in the surrounding sands; it appears to consist of grey slightly loamy clay, light brown near the surface, with very small fragments of flint.

On the dip-slope of the Pecten-bed, the soil is brown sand with numerous fragments of decomposed ferruginous rock and occasional pieces of flint and pebbles of old rocks.

Further north on the surface of the Sand-waste on the dip-slope of the Pecten-bed, east of Messingham, and amongst the Sands occurring in patches on the high ground and covering extensive areas in the lower district, north of Messingham, fragments of flint are found here and there.

Between Messingham and the Humber the only direct evidence of glacial action is furnished by a small patch of grey Boulder Clay with flint fragments, and whitish marl overlain by Gravel, on the north side of the valley by the road from Frodingham to Burton, east of Flixborough. This patch is entirely surrounded by Sand; from its isolation it is not possible to say whether it represents Chalky Boulder Clay or the accumulation of a later period.

On the east side of the road between Alkborough and West Halton numerous pieces of flint are scattered over the surface, also at about half a mile west of West Halton, and between Walcot and Coleby, at half a mile from the latter; these may be relics of Boulder Clay, or of Gravel.

The sloping ground, on the lower part of which Bishopthorpe is situated, is composed of brown loamy soil with numerous bits of flint; this may be gravel soil, as gravel was met with in sinking a well at the turning to the Farm, and is exposed on the south side of the stream, west of the Whitton and the West Halton road, and south-west of Bishopthorpe.

Old Gravels.

Whilst the gravels we are about to describe may be unhesitatingly referred to the same general period, except perhaps those on the Oolitic escarpment (first described in the detailed notes), it is not possible to prove the former continuity, or actual contemporaniety of isolated patches.

With the doubtful exception above mentioned, these gravels are relics of a long period of denudation, intervening between the accumulation of the Chalky Boulder Clay and the deposition of the Low-level deposits of the Ancholme Valley, and as such it is only natural to find their sites, even in contiguous places (as near Flixborough) varying considerably in height.

As the deposits of the Ancholme Valley are regarded as partly Glacial it is more than probable that the sands underlying the Peat and Alluvium of the Trent flats, and the stiff laminated clay of the Humber and Trent Valleys are of the same general age, if not strictly contemporaneous. So that, unless these valleys had been filled with a great thickness of Newer Glacial deposits, it is difficult to assign a Post-Glacial age to the Old Gravels, their positions pointing to a date of formation intermediate between the accumulation of the Chalky Boulder Clay on the one hand and that of the Brown Boulder Clay and Low-level Clay on the other.

(a.) *On the Oolitic escarpment.*

By the upper road (*i.e.*, the road on the top of the Oolitic escarpment) to Kirton, at about 8 chains from the south margin of Sheet 86, a small

deposit of Gravel, of worn fragments of Lincolnshire Limestone, occurs. A similar Gravel forms a small patch by the same road near the cross roads north-east of Grayingham: it is shown in a quarry by the road. On the east of the Gravel patches the soil is brown and loamy with Oolitic rock fragments, and occasionally bits of flint.

At about 30 chains north of the first letter *n* in the word Maston, on the Map a Gravel patch makes a small feature in the upper part of the Oolitic escarpment, obscuring the junction of the Basement Oolites and Upper Lias.

By the road to Botteaford, near the summit of the Oolitic escarpment, the lowest beds of the Kirton series are exposed in a quarry, under 4 feet of Gravel composed of worn materials of Lincolnshire Limestone.

In the Spring Wood boring the first bed mentioned is "Gravel, round limestone and sand" 18 feet, upon 10 feet 4 inches of red sand. This is probably broken limestone, as there is no Gravel on the Oolites in the vicinity.

At Wressle Houses a patch of Gravel, about a foot thick, is shown on the upper beds of the Kirton series, in the southernmost quarry.

(*b.*) *Gravels in the Boulder Clay area, Ancholme Valley district.*

A small patch of Gravel has been mapped on Gravel Hill, near Thornton-le-Moor, by Mr. Strangways, who mentions the occurrence of "a little gravel in some of the ditches and ponds," but the name is deceptive, as "no gravel is worked in this district," "the general character of the fields is clayey" "with a little marl (gravel) in places." This is probably the same as that between Cadney and Kelsey.

The South Kelsey Gravel is exposed in a gravel pit thus described by Mr. Strangways: "8 feet of rounded gravel, stratified, on Boulder Clay. Some shell fragments (? derivative). At the southern end it is coarse and unstratified with some angular flints. The Gravel is composed almost entirely of rounded flint."

Cadney Gravel.—The limits of the Cadney Gravel are defined by level on all sides except the east, where it overlies Chalky Boulder Clay. The Gravel has been extensively worked in a large overgrown pit, in a piece of waste ground in the village. It consists principally of flint fragments more or less worn, interstratified with coarse sand, &c., the whole being pale brown or buff in colour. The Gravel is generally indicated on the surface, especially on the south and west parts of the patch, by worn flint fragments. Near the fork in the lanes west of Cadney, fine, pale brown, buff, and grey, laminated, cohesive sand was exposed in a drain.

Wrawby Gravel.—Wrawby Hill is capped by a patch of Gravel resting upon Chalky Boulder Clay which it overlaps on the east of Wrawby. The actual junction of the Gravel and Boulder Clay is not exposed in section. The connexion between the Wrawby Gravel and the Low-level deposits of the Brigg district is very obscure, and also its relation to the small adjacent Gravel patch which extends to Brigg Station. This smaller patch consists of similar Gravel of well-worn flints, associated with sand. The southernmost gravel pit in the Wrawby patch, at the letter *H* in the words Union *H*ouse on the Map, affords no section, but well-worn flint fragments are thickly scattered over the soil.

On the upper part of the slope to the south of the western end of Wrawby village the Gravel is exposed to a depth of 15 feet in a pit. The deposit is coarse and fine, and composed chiefly of flint fragments, but it also contains pieces of Chalk, and of grits foreign to the district.

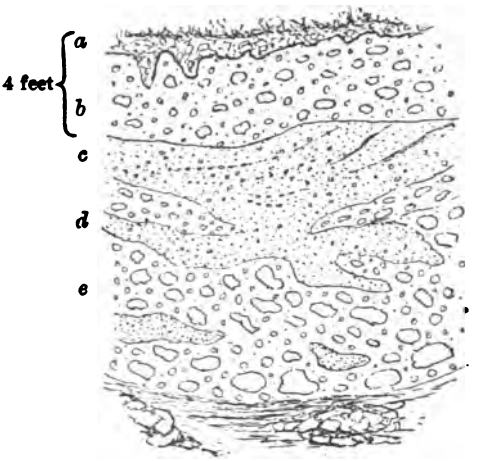
The flints are for the most part well worn, and are largest in the lower part of the section. The matrix is light brown and cream-coloured sand. The Gravel is associated with irregular lenticular strips of sand and very

fine gravel. The accompanying sketch shows the distribution of the finer and coarser materials:—

a. Pipes of brown soil with angular flint fragments.
b. Yellowish gravel.
c. Irregular lenticular courses of fine gravel and sand.
d. Whitish sand dovetailing into gravel of average-sized fragments.
e. Coarser gravel with lenticular patches of coarser sand.

FIG. 3.

Section in Wrawby Gravel Pit.



Old pits, in which no sections are now visible, are met with near Wrawby Church and the road to Elsham west of the north part of Wrawby.

At about 10 chains from St. Helen's House, north of the words Gorse Cover, on the Map, a small pit shows well-worn, pale buff Gravel.

Near Wrawby Mill a pit shows Gravel of worn and fractured fragments of flint and Chalk in pale brown and whitish sand, with curved lenticular strips and beds of fine sand, with coarser seams at from 2 to 3 feet from the surface. The pit is from 5 to 8 feet in depth; in the deepest part the gravel gives place to sand irregularly; the sand contains both coarse and fine grains intermingled; the stones in the gravel are for the most part small, but fragments as large as a clenched fist are present in it.

In an adjacent pit there is an exposure of 7 feet of well-worn flint and Chalk Gravel in a sand matrix, as above described, with one or two small lenticular strips of fine sand with alternating coarser bands.

A patch of Gravel at Barnetby Gorse Hills has been mapped by Mr. Strangways, who describes it as "Chalk gravel, angular and rounded."

(*c*.) *Gravels in the Liassic area.*

Gravel east of Northorpe.—A small patch of Gravel, apparently resting on Boulder Clay, makes a feature, at 90 chains from Northorpe Station, in a direction E. 10° N. A pit in it shows a section 10 feet deep:—

	Ft.	Ins.
Brown loamy surface soil with pebbles and broken pieces of flint, upon brown loamy clay with pebbles and broken flints occuring in pipes in gravel -	3	0
Gravel composed of pebbles, subangular and nearly angular fragments of Liassic and Cretaceous rocks, worn specimens of *Gryphœa* and *Belemnites*, in a coarse sand matrix composed of similar materials -	7	0

The upper part of the gravel for from 3 to 4 feet shows no trace of bedding, but lower down the fragments are distributed with regard to

gravity, and rather fine gravel and seams of coarse sand are intercalated with the larger gravel.

Blyton Gravel.—The Blyton Gravel patch bounds the Alluvium of the Blyton valley on the east and extends from Long Bridge northward for 50 chains on the west side of the road to Scotton Common; on the east side of the road it sends out an arm, which crosses the road to Northorpe at the letters *g* and *B* in the words Long *B*ridge on the Map, where it has been exposed in pits not now affording sections. In the northern part, and just north of Blyton, the Gravel is exposed in several pits.

In one pit north-east of Blyton Church, near the road to Scotton Common, false-bedded stratified Gravel is exposed to a depth of 6 feet 6 inches. It consists of two false-bedded masses of gravel, composed of worn fragments of Lias and of Rhætic Beds and angular bits of flint and quartzite pebbles, separated by a 6-inch seam of fine brown sand. The Gravel matrix is very coarse sand. The upper bed of gravel is 3 feet thick, and the lower is exposed to a depth of 3 feet.

Hardwick Hill Gravel.—Hardwick (pronounced Haddick) Hill, near Scotter and Susworth, rises from a low Sand tract bordering the Alluvium on the north and west. On the east it is connected with the high land of Scotton Common, near Hardwick Warren House; on the south it extends in a ridge as far as the village of Laughton. West and south-west of Hardwick Warren House Keuper Marls are exposed on the slope through the enveloping Sands. The hill is capped by Gravel, consisting of worn and subangular fragments of quartz, quartzite, grit, green Keuper sandstone, and Liassic (? also Oolitic) stones. The Gravel is concealed for the most part by Blown Sand, which has swept up the slopes of the hill, obscuring its junction with the Keuper, save in the two instances, where the latter is exposed, as before mentioned.

The Gravel is exposed to a depth of from 3 to 4 feet in pits on the hill, on the north of the road to Ferry Flash. Near the road, on the south side of the hill, springs are given out, apparently from the junction of the Gravel and Marl. Near Laughton Mill and Laughton there are several pits by the path and on the east of it, one being 12 feet in depth.

The only exposure worthy of record is near the eastern boundary of the patch in a gravel pit recently worked at the letter *g* of the word Lo*dg*e, on the Map. In this pit 6 feet of Gravel is exposed; it is roughly sorted into masses of average-sized and of very small fragments, mostly of foreign derivation, with bits of flint more or less angular, in a reddish sand matrix. Apart from the rough distribution of materials, no lines of bedding are apparent in the deposit. A large boulder of green metamorphic rock 2 feet 10 inches × 1 foot 10 inches × 1 foot partly concealed by Blown Sand was noticed near the path junction not far from Hardwick Warren House, at the foot of Hardwick Hill. The base of the boulder is embedded in Keuper Marl.

Scotter Gravels.—There are three patches of Gravel in the vicinity of Scotter.

Between Scotterthorpe, Scotterwood, and Scotter, a Gravel patch of considerable extent affords one section, a small pit, in densely packed gravel, composed of rather small worn Lias fragments, with a general mortar-like appearance, owing to efflorescence of Alum. The pit is at the letter *e* in the work Beck, or the Map.

A large Gravel patch occupies the slope, and rests on the summit of the higher ground in the south part of Scotter. Near its western termination, not far from the road to Scotton Common, the following section is shown in a quarry:—

	Feet.
Coarse gravel of worn Lias fragments - -	1 to 2
Greyish white sand of similar material to the gravel, with numerous fragments of Lias shells (*Gryphæa*, &c.) and presenting a stratified appearance -	1 to 2
Lias limestones and clay.	

Near the Mill (near Scotter Church on the south-west) a large pit exposes Gravel, in one part, to a depth of 12 feet. The Gravel is of a dirty white or dull buff colour, and is composed of worn fragments of Lias lime-

stones arranged with regard to gravity, showing false-bedding in places with a northerly dip of about 15°.

The gravel pits near Scotter Vicarage are for the most part concealed by grass, &c.

In one place Gravel, of worn fragments of Lias in a drab sandy matrix, is intercalated with irregular courses of sand.

In the northernmost part of Scotter, on the east of the stream, the high ground terminates in a rounded hill, or knoll-feature, formed by a Gravel patch. A large pit, 12 feet in depth, shows pale drab gravel of Lias fragments, generally well worn and of various sizes, in fine gravel of similar materials, bedding is indicated in one place by a general assortment of materials with regard to gravity, in impersistent bands, in another place current bedding is shown. The part exposed is for 5 feet downward from the surface, the section being elsewhere grass-covered.

About half-way between Scotter and Messingham, a Gravel patch occupies a depression and mantles up the slopes on either side.

A pit in a field by the road shows 5 feet of Gravel of Liassic fragments, more or less worn, and occasionally of quartz and flint; the materials are distributed with regard to gravity, in even beds, thus :—

Brown soil.
Stones of various sizes in a fine gravel matrix.
Band of rather small gravel.
Very coarse sand seam of Liassic materials.
Gravel of average-sized stones.
Seam of fine sand.
Gravel of medium sized fragments.

Yaddlethorpe Gravels.—On either side of the valley south of Yaddlethorpe, and west of the road to Frodingham, patches of Gravel occupy part of the slopes.

On the south of the valley the Gravel makes a subsidiary feature on the slope. Due east of Messingham Mill, a pit, mostly overgrown, affords evidence of the Gravel upon Lias clay and limestone.

On the north of the stream the Gravel forms the slope and summit of the hill, it is exposed in three pits.

The westernmost pit shows about 20 feet of gravel, chiefly composed of worn Liassic limestone fragments, often of very large size, bedding is roughly indicated by the assortment of material; but, although deeper, the section is by no means so interesting as that in the easternmost pit.

The easternmost pit is about 10 feet deep; bedding is shown by the distribution of the coarser and finer gravels and brown sand, giving dips which seem to be in southerly and westerly directions.

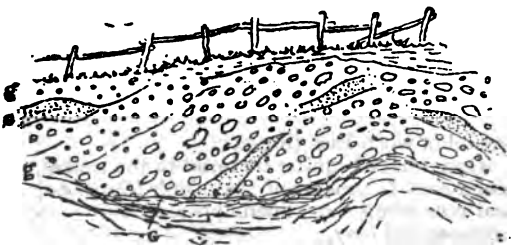
In the north side of the pit the materials are distributed as shown in the accompanying sketch :—

FIGS. 4 and 5.

Sections in Gravel Pit, south of Yaddlethorpe.

FIG. 4.

North Side of Gravel Pit.



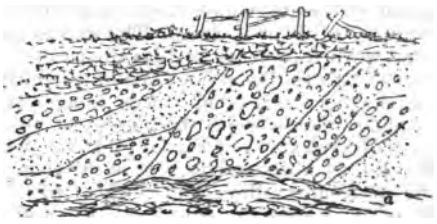
s. Brown Sand of broken Liassic shells, &c.
g. Gravel of small and average-sized fragments.
g. Gravel of large and average-sized fragments.

On the west side of the pit Gravel of small and average-sized fragment forms the surface; it rests upon brown sand, succeeded by coarse and rather fine mixed gravel, in which there is an impersistent seam of sand.

The south side of the pit exhibits the relations shown in the accompanying sketch:—

FIG. 5.

South side of Gravel Pit.



b.s. Brown soil.
ss. Brown sand.
gg. Fine gravel.
GG. Coarse and medium-sized gravel.

At (*a*) the section is about 8 feet deep; at (*b*) it is about 7 feet.

The northernmost pit is small and unimportant. The Yaddlethorpe Gravel is bounded by a patch of sand on the north; although the way in which the sand dovetails into it in the pits suggests the outward passage of the Gravel into sand, there are no patches of sand *in situ* which could be proved in any way contemporaneous with the Gravels.

At a mile west of Ashby, on either side of the road to Burringham Moor, the steeper slopes are broken by small Gravel features. On the north side of the road the Gravel is exposed in a small pit, and consists of worn Liassic materials; the patch on the south side of the road is indefinite.

Coneysby Bottom.—On the south side of the stream, 70 chains from Flixborough Old Church in a direction due east, a pit exposes well-worn Gravel, but angular fragments of flint are plentiful. Most of the harder beds of the Lias appear to have contributed to the formation of the Gravel. Nodules with *Ammonites capricornus* occur in it. Intercalation of finer material gives to the deposit rude traces of bedding in the western part of the pit.

A large worn boulder of yellow Oolite, 4 feet long by 2 to 3 feet deep, occurs at the base of the deposit in the eastern corner of the pit; it is embedded in white and drab marl, very irregularly overlain by gravel.

Near the boulder on the east side, about 4 feet of whitish marl is shown under 5 feet of gravel, whilst on the other side 2 feet of marl, apparently containing a nest of gravel, is overlain by about 7 feet of gravel.

On the north side of the stream a large pit shows a small patch of Gravel apparently resting on Boulder Clay. This Gravel is cemented into a breccia by ferruginous infiltration; in places it contains fragments of Lias, flint, &c. and a boulder of Oolitic rock; Boulder Clay is shown in a pit on the west side of the road. The gravel occurs on the slope and appears to be a small outlier of the larger patch on the south side of the valley. It is surrounded by Sand, probably blown.

Flixborough Gravels.—West of Flixborough a patch of Gravel occurs on the hill-side, at from 80 to 100 feet, about, above the Alluvium. The deposit is exposed to a depth of 5 feet in a pit: it consists of gravel and coarse brown sand, composed of local Lias fragments and occasionally bits of selenite. Many of the Lias fragments are of large size and but slightly worn. The general distribution of the materials gives the deposit a stratified

appearance, and in one place, near the surface shows an indication of current-bedding. The Gravel rests on a shelving surface of Lias rock, forming the floor of the pit. The boundaries of this patch are indefinite; it occupies an intermediate position between a larger Gravel patch north of Flixborough (with which it might have been once connected) and a small patch bordering the Alluvium close to its southern termination.

The lower Gravel patch is well exposed in a large pit, on the south side of the road from Flixborough to Flixborough Stather. The distribution of the stones with regard to gravity shows bedding with a south-westerly dip; bedding is also still more markedly indicated by strips of black sand, composed of lignite, which occur here and there irregularly. The section is from 5 to 10 feet deep. The stones are seldom large; they consist of well-worn fragments of Lias limestone; a fragment resembling Sunstone (top of Rhætic Beds), and bits of selenite were obtained in the Gravel. The northern extension of this Gravel is very doubtful it does not appear to be connected with the patch just above it.

The patch of Gravel north of Flixborough occurs on the slope, at about the same height as that on the west of Flixborough, from which it is separated by a stream valley; but it rises with the slope, so that the greater part of it is probably not much short of 200 feet above the sea. This Gravel has been worked by the path to Burton, and near its western and lower boundary.

There may have been an extensive deposition of Gravel on the summit of the Liassic escarpment north of Flixborough, as traces of gravels of Liassic materials are shown by the road to Waterton Clough on the south of Burton, overlain by the Sand which extends south-east from Burton. A trace of similar Gravel is also evidenced near the source of a spring at the top of the escarpment about half a mile north from Burton Church.

Whitton Gravel.—Whitton Church and the northern part of the village is upon Gravel, which passes upward from the level of the Alluvium in a south-westerly direction. How far this deposit may extend on the summit of the Liassic cliff is very doubtful, as the soil might be taken as indicative of Lias *in situ* near the escarpment, but south of Whitton it is all sand. Opposite Whitton Pier, from 2 to 8 feet of Gravel is shown in a quarry, resting on Lias at about 30 feet above the Alluvium.

Outside the pit, the Gravels rest upon brashy ferruginous limestone, at from 10 to 15 feet above the Alluvium. The section shows:—Brown gravel of worn Lias stones upon soft brown sandstone and sand, with derivative shell fragments, dividing the gravel irregularly and attaining a thickness of 2 feet, the sandstone being uppermost. Below this bed the gravel is consolidated in places into a bed 1 foot in thickness, containing large fragments in a matrix of finer gravel and coarse sand.

Near Whitton Church a large gravel pit shows the following section from the surface downwards:—

	Ft.	In.
Very coarse gravel of worn Lias stones - -	20	0
Brown sand, gravelly in the upper part, from 1ft. 4in. to 3 ft. 6 in. thick averaging - - - -	2	5
Gravel; stones not so large as in upper bed, exposed to a depth of - - - - - -	5	0

The lower gravel bed thins out upwards against the sloping quarry floor of Lias rock, so that on the south, or landward, side of the pit the section is not more than 22 feet altogether. By the Alluvium the Gravel is represented by a bank of large worn stones in a matrix of coarse, brown, consolidated sand, in part made up of broken derivative shells. At 44 yards further east patches of consolidated gravel of finer material, with false-bedded courses of brown sandstone, are visible.

The sloping ground on which Bishopthorpe is situated is probably composed of gravel with broken flints, as gravel was encountered in sinking a well at the turning to the Farm, and is exposed in a small pit not far off on the south-west That the Whitton Gravel is continuous under the intervening Sand or contemporaneous with the Bishopthorpe Gravel is very doubtful, not to say improbable.

The discrepancies in the height of the Whitton Gravels are due to the fact that they have evidently been banked up against a steep slope of Lias rock; the same is the case in the upper Flixborough patches and elsewhere.

The following notes on the older gravels in the Triassic area of the Isle of Axholme are by Mr. Cameron, who surveyed the area west of the Trent:—

(*d.*) *Gravels West of the River Trent.*

In places in the neighbourhood of Owston, a deposit of flat fragments of Marl is found at 3 feet below the surface.

At High Burnham, the most elevated spot in the Isle of Axholme, 200 feet above sea level, Gravel is exposed. It consists of coarse red sand with numerous quartz pebbles and fragments of Marl, with a small proportion of Triassic sandstone, and an occasional fragment of igneous rock. From 4 to 5 feet of the Gravel is exposed under 1 foot of pebbly soil.

In the south part of Low Burnham, stratified sand and gravel is exposed to a depth of 5 feet. The Gravel consists of flattened fragments of Marl with a few well-worn fragments of quartz, grit, and igneous rock (? basalt).

At the signpost on the hill top, south of Epworth, a trace of Gravel is evidenced by sand, often black, containing stones here and there.

At Beltoft, gravel pits on the brow of the hill overlooking the Alluvium, show Gravel to a depth of 8 feet, in beds dipping sharply in the direction of the slope of the hill. The gravel consists of flattened Marl fragments with a smaller proportion of quartz, coarse grit, ironstone, and igneous rock—the pebbles in a matrix of red sand.

A trace of similar Gravel to that at Beltoft occurs in the most southerly of the plantations at Moonfield Thick.

The Belton Gravel patch is exposed, to a depth of 8 feet, in pits at the south end of Belton Hill. It consists of stratified sand and gravel, dipping with the slope of the hill. The gravel is chiefly composed of flat fragments of green indurated Keuper Marl and Sandstone, fragments of ironstone, quartz pebbles, &c.

Wroot is a low hill surrounded by Peat-flats; the soil is Gravel, except on the south, and in places on the east and north, where fine Sand has been banked up in mounds by the winds.

The Gravel is exposed in two pits. One of these exhibits 9 feet of red sand and gravel.

The other pit also affords a section 9 feet in depth, consisting of coarse and fine gravel interstratified with seams of fine sand, about 4 inches thick.

The Gravel consists of flat Triassic fragments, quartzites, and a few subangular fragments of Carboniferous limestone. The colour is red, suggesting the idea that the deposit is of no great thickness and rests on Triassic Sandstones.

On the east of the hill, south-east of Wroot village, greyish clay with stones is exposed in a ditch.

At Misson stratified red sand and Gravel with many quartzites, occurs, as at Wroot.

On the east of Crowle, Gravel, chiefly composed of flat Triassic fragments, interstratified with sand, is exposed to a depth of 15 feet in pits in the south part of Crown Hill.

On Danes Hill near Eastoft, in the Alluvium north-east of Crowle Hill, the Gravel is concealed by a sand surface.

A. C. G. C.

Low-level Deposits of the Ancholme Valley and Brown Boulder Clay.

On the lower ground bordering the Alluvium of the Ancholme, on either side, tracts of clay, sand and fine gravel frequently occur.

The Clay has been frequently noticed at a level some 2 or 3 feet lower than that of the adjacent Alluvium; but it also occurs on the slopes up to 30 or 40 feet above the Alluvium, and in places it contains chalk fragments.

In many exposures, more especially on the west side of the Alluvium South of Brigg, the gravels and sands rest irregularly upon a bed or seam of reddish grey-mottled Clay, from 1 to 4 feet thick, which is almost invariably found to rest upon sand and gravel.

Early in the year 1883 Mr. Jukes-Browne endorsed an opinion I had temporarily entertained before, and had even partially mapped in accordance with, viz., that there were two Glacial Clays in the district, the Chalky Boulder Clay, and a Low-level Clay of newer glacial age. That view was adopted, and in accordance with it the drift mapping has been re-modelled.

As far as the mapping of these Low-level deposits is concerned it makes very little difference whether we include them in the Glacial or Post-Glacial series; with Mr. Jukes-Browne* I regard the Clays and subjacent deposits as of late glacial age, but consider the age of the overlying sand and gravel as doubtful.

There are very important considerations, however, involved in the assignment of a glacial age to these deposits; for as we find them beneath the Alluvium of the Ancholme valley, and occupying, here and there, the low ground on its borders, the Ancholme and its tributary valleys would have been excavated to their present depths at or before the close of the Glacial Period, which would scarcely leave any denudation to be effected in that district in Post-Glacial times. Again, if we connect in fancy the Gravels on the Chalky Boulder Clay at Wrawby and Cadney, the measure of denudation since the accumulation of the Chalky Boulder Clay would be represented by the heights of these gravels above the neighbouring valley bottoms.

Notwithstanding the probability that the Low-level deposits of the Ancholme Valley are partly represented by the sands and laminated Warp of the Trent, Ouse, and Humber, these beds are not included in the present description, as it is impossible to describe these latter deposits apart from the Warp and Peat.

Their irregular distribution necessitates a description of the Low-level deposits in the following order in the detailed notes:—As far north as Cadney on the east of the Ancholme; south of Brigg, on the west of the Ancholme; the Brigg, Wrawby and Howsham district; north of Elsham, east of the Ancholme; west of the Ancholme from Brigg northward.

* *See* "Boulder Clays of Lincolnshire" by A. J. Jukes-Browne, *Quart. Journ. Geol. Soc.*, vol. xli., p. 114.

Owing to the very indefinite age and relations of the members of the Low-level series it has been found impossible to avoid incidental and even descriptive mention of Blown Sands and of Alluvial deposits in the following detailed notes:—

(a.) South of Cadney.

At the western termination of the hill on which Thornton-le-Moor stands, a spread of sand and gravel forms a very low feature with great difficulty separable from the Alluvium. A drain by the letters *rnton* in the words Tho*rnton* Carrs, on the Map, in two or three places showed dark grey Clay, which, being penetrated by the spud, was found to rest on sand.

On the south of Owersby Drain and north and north-west of Gullham a considerable spread of sand, often devoid of stones, bounds the Alluvium; it may be in part Blown Sand.

Oxford Clay is exposed in a pond on the north side of Winghall Farmyard, separating the Chalky Boulder Clay from a deposit of gravel a few feet below it, on the south of the farmhouse. The gravel is exposed to a depth of 5 feet in a pit; it consists of well-worn stones, for the most part small, of flint, chalk, &c., well stratified, thin beds or courses of coarse sand and fine drab mud alternating with the gravels. The gravel does not appear to be more than 10 feet in thickness. Just below the pit, at a spring, typical Low-level Clay is shown by a pond; the gravel seems to rest on it. This gravel should be specially compared with that at the letter *r* in words Little Carr Drain south of Elsham Station.

The height of the deposits at Winghall is somewhat exceptional; they may cover the lower ground, but no reliable evidence was obtained.

Holme Hill is a very low mound of Oxford Clay, for the most part shrouded and surrounded by sand and gravel, very variable in thickness; the Oxford Clay is apparently at the surface in the farmyard and for 12 chains to the north of it.

North, south, and east of Ings House brownish sand, apparently devoid of stones, containing small ferruginous concretions, mantles up the Oxford Clay slopes, in places very nearly to the level of the Chalky Boulder Clay, as in a drain by Decoy House Lane, where Oxford Clay is shown for a chain between the Boulder Clay exposed above, and sand below. East of Ings House, from the material turned out of the the drains the sand appears to be gravelly and to be associated with brown Clay, which might belong to the Low-level series. The sand between Gadney and Ings House is full of ferruginous concretions, in places.

On the south of the village of Cadney, the lower ground bordering the Alluvium, consists of red-brown, grey-veined, Low-level Clay; this Clay is separated by a strip of Oxford Clay, on the slope, from the southern margin of the Cadney Gravel for more than half a mile. At 50 chains from Redcar Bridge the Clay seems to bound the Gravel.

South of the letters *ney* of the word Cad*ney*, on the Map, the Clay comes high up the slope to the junction of the Chalky Boulder Clay and Cadney Gravel. The Chalky Clay is under the east end of the Cadney Gravel; but there does not appear to be any evidence to show that the Cadney Gravel anywhere, at contact, overlies the Low-level Clay.

The slope between the western end of the Cadney Gravel and the Alluvium is very indefinite, it may be either masked by talus from the Gravel above, or formed of sandy material belonging to the Low-level series.

At the letter *w* in the words Newstead Priory, on the Map, brown and grey Clay, containing fragments of flint, occasional pebbles of quartz and pieces of Oolitic rock, is exposed in a ditch (Boulder Clay or *remanié*).

Further south brownish sand is shown, apparently in irregular association with the Clay above mentioned.

The sand forming the hill between Newtsead Priory and Sand Hill Farm may belong to this series, but in the districts to the south the

Kellaways Rock is so largely composed of sand, from which no doubt these Low-level sands were principally derived, that we are always compelled to mention them in indefinite terms.

The Oxford Clay, north of Cadney, is bounded on the east by a long strip of sands and gravels, separating it from the Alluvium between North Carr Bank and Kettleby Dyke. The gravel makes a feature at its northern termination, near Kettleby Dyke; it consists of coarse well-worn flint pebbles. This gravel which passes under the Alluvium probably belongs to the Low-level series.

(b.) South of Brigg, west of the Ancholme.

At about 12 chains west of the Ancholme at the southern margin of the Map, in a drain, the red-brown, grey-mottled, Low-level Clay is exposed, under yellowish sand and gravel, the whole capped by from 2 to 3 feet of Peat. The Low-level Clay is also exposed under the Alluvium west of the above at 0° 29′ longtitude.

By Black Dyke Oxford Clay is exposed; not far to the west of the exposure the Low-level, red, grey-mottled Clay is shown under gravel beneath the Alluvium in Black Dyke.

The Waddingham valley west, south, and east of Old Mill consists of a flat tract of fine gravel, which is indistinguishable from Alluvium by level. In this instance the gravel flat is regarded as Alluvial.

From Hibaldstow to Priestland Cover a continuous stretch of flat land, composed of fine gravel at the surface, conceals the junction of the Great Oolite Clay and Limestone, and of the Great and Inferior Oolites. The parts of this tract which are in line with, or a continuation of, the stream-valley gravels on the west we regard as recent gravelly Alluvium, and those parts which do not betray the same intimate connexion with the existing drainage, and are found to overlie the Low-level Clay irregularly (as the South Ferriby cliff gravel overlies it) we regard as sands and gravels of the Low-level series. The gravels are almost invariably composed of fine Oolitic detritus, not much worn; they are exposed in most of the drains, for from 2 to 5 feet. near Hibaldstow Lodge, Redbourne River Head, Beanland Cover, at Priestland Cover, and other places. At Hibaldstow Lodge and east of Beanland Cover the gravel makes a very indefinite boundary with the Oolitic rocks.

From Wootham Hill southward the higher part of the Kellaways Rock feature is composed of sand, in places containing bits of flint, especially on the north of Furze Closes. North of Waddingham Holme yellowish and whitish sand is exposed. The relations of the Kellaways Rock and underlying beds are so enigmatical that we are disposed to regard these sands as drifts possibly belonging to the Low-level series. Similarly, on the south of Redbourne Hays, sand soil with flints masks the Kellaways Rock feature; but near Paradise, a farm in the south part of the tract, a patch of gravel occurs; and in the ditch bounding Atkinson's Cover on the east, in one spot, greyish Clay full of race was spudded through to fine gravel; further north clayey and loamy material is shown in the ditch. About a quarter of a mile north-west from Wootham Hill houses, characteristic red-brown Low-level Clay is exposed for 6 chains west from the bend in the road, a few chains south of Paradise.

At 20 and 30 chains from Waddingham Church in a north-west direction red brown grey-veined Clay was noticed in association with sand and gravel. Between the bends in the road on the north of, and near, the letter W in the word Waddingham, on the Map, grey, very plastic, Clay was spudded into to a depth of 2 feet, when faint indications of mottled sand with small stones were obtained. The Low-level Clay extends from this eastward, but on approaching the Kellaways escarpment its place is taken by sand and gravel. South of the letter *b* in the words Na*b*s Hills, on the Map, bluish dicey Clay has been noticed by the road, but it may be the Clay above the Cornbrash.

At Waddingham Church, near Old Mill, at the letter *B* of the words *B*lack Dyke, and further north, patches of sand with bits of flint occur.

By the stream-drain on the Map, north of the letter *d* in the words Beanland Cover, red, grey-veined Clay is shown under gravel, the upper part of which is taken as a comparatively recent redeposit.

At about a quarter of a mile due north of the north-east corner of Beanland Cover reddish-brown Clay, apparently belonging to the Low-level series, containing race, was spudded into in a ditch; it seems to pass under sand and gravel on the north and west. The deposits of the Low-level series are well exposed in ditches and drains south of Redbourne River Head; at 50 chains from the houses red grey-veined Clay was observed at the surface. The Clay is very well exposed in a drain running due south from Redbourne River Head; in one spot, near the houses, the section shows chocolate and purplish-brown Clay overlain by gravel and sand, and resting upon gravel.

On the east of Redbourne Hays a patch of gravel, chiefly composed of angular flints, rests on grey clay, either Oxford Clay soil with bits of flint, or Low-level Boulder Clay.

Clay Dyke intersects a low mound of sand with bits of flint, extending northward from Ryecroft Hill; the connexion of this sand with the Low-level Clays is not shown, the lower part of it may belong to the Kellaways. The surface sand of Gander Hill may belong to this series, but below it is Kellaways. At Gander Hill a patch of Low-level Clay rests on the Cornbrash, and is exposed in a ditch at a few yards from the Kellaways Sand-pit.

In Clay Dyke, due north of the first letter *R* in the words Redbourne River Head, the following section is visible:—

Sand upon fine brown gravel, very irregularly overlying:—
Brown and grey Clay, apparently passing downwards into bluish clay with gravel.

A fine ditch section by the road from Low Bank to Hibaldstow Mill, where the drain crosses it, shows—

	Ft.	In.	
Sandy soil, with fine gravel at the base resting irregularly upon the Clay below - -	3	0	
Red-brown, grey-mottled Clay, grey at the base -	2	0	to 3 ft.
Grey and yellowish-brown sand and gravel, about	1	0	

Stiff, brown, grey-veined, Clay, a continuation of that in the ditch, is exposed by the road for 5 chains eastward, concealing the Upper Estuarine Beds to within 2 chains of their junction with the overlying Great Oolite Limestone.

By the drain east of the Mill, in Hibaldstow, 3 feet of gravel, of small Oolitic fragments in brown sandy loam, rests upon red-brown grey-veined Clay. Between this and the road from Hibaldstow Mill to Low Bank the Low-level Clay is exposed by the drain in places under an irregular capping of sand and gravel.

In Low Bank, near Clay Dyke, gravel, of small fragments of Oolite and flint in drab sandy loam, is exposed. Between Low Bank and the Alluvium west of Redcar Bridge Low-level red-brown Clay is shown.

Near the Mill in Hibaldstow, on the north, a ditch presented a most interesting section, consisting of:—Gravel of unworn and subangular fragments of Oolite, resting irregularly upon red-brown Boulder Clay, marbled with grey, and stiff blue clay, with whitish sandy patches, containing very small fragments of Oolite. The gravel above seems to pass into sand both apparently occurring in lenticular seams in the uppermost part of the Clay.

The following may be advantageously compared with Winghall and Little Car Drain gravels:—

The patch of Great Oolite shown on the Map between Hibaldstow Mill and Low Bank Drain forms a low hill feature. On the south of the road from the Mill to the drain the slope and western part of the summit of this feature is formed of Oolitic gravel which is exposed in a pit, about 5 feet in depth. The gravel is of a light brownish colour, and composed

of fragments, seldom large, more or less worn, chiefly derived from the stone bands in the Great Oolite Clay. The distribution of the fragments and the presence of a thin bed or seam of brown sand near the top of the exposure indicate horizontal bedding.

At about a quarter of a mile east from the Mill in the north-east part of Hibaldstow fine Oolite gravel makes a flat tract, from which the ground rises in a mound, facing westward, to the summit of a low hill, on which a farm, not shown on the Map, is situated. From the base of the slope to its summit a small nearly circular patch of Oolitic gravel is indicated on the surface, and exposed in a pit to a depth of 3 feet. The pit shows gravel of Oolitic fragments more or less worn and distributed in coarse and fine beds and seams, dipping sharply westward, down the slope. Near the northern margin of the gravel Oolitic rocks are at the surface, but on the east, where it is not defined by feature, it is hard to say whether Upper Estuarine Clay or Low-level Clay bounds it.

(c.) *Brigg, Howsham, and Wrawby district.*

By the Railway near the high road east of Skegger Beck a patch of gravel is exposed in a pit to a depth of 5½ feet; it consists of light brown sand of medium sized and rather fine grains of flint and quartz, worn and unworn, with small subangular fragments dispersed throughout in irregular impersistent streaks, the stones are flint, Chalk, and occasional fragments of old rocks.

The following notes are furnished by Mr. Strangways, they may refer to beds in the Low-level series:—

Grasby Low Cottages; Alluvium over gravel in the Beck.
Grasby Low Farm; sand over gravel.
Near Wether Plat; rounded Chalk gravel.

C. F. S.

The sides of a drain,* running through Froghall and Low Barf, from Kettleby Dyke to South Bank, exhibit a very irregular association of sand and Clay. In one spot 10 feet of sand in one bank is faced by red-brown Clay on the other. Light brownish sand, with small broken and worn flints, occurs in patches on, and apparently in, brown Clay, which is exposed to a depth of 10 feet. Pockets of small broken and well-worn flint gravel occur here and there in the red-brown Clay.

In one spot the section, downward, is as follows:—

	Ft.	Ins.
Indian-red-brown clunchy Boulder Clay with bluish-grey mottling, containing a few pieces of flint, &c. - - - - -	3	0
Brown loam with grey clayey patches, making a tenacious loam, with small bits of flint, rather numerous - - - - - about	2	0
Oxford Clay with brown nodular stones.		

Near Kettleby Dyke the sides of the drain, from 5 to 10 feet deep, are composed of sand, which conceals the Low-level Clay for some distance eastward.

At about a quarter of a mile east-north-east from Howsham Barff a ditch section shows brownish sand, with angular flints here and there, irregularly overlying red-brown, grey-mottled Clay without stones, exposed to a depth of from 3 to 4 feet; this Clay near Skegger Beck, where it forms the entire section, is about 5 feet thick.

At half a mile from Howsham Barff, in a direction E. 22° N., red-brown, grey-mottled Clay is shown under sand and gravel.

It is very difficult to determine what to call the gravels and sands of the low lands on the west of Bigby and Barnetby.

* *See* figure in *Quart. Journ. Geol. Soc.*, vol. xli., p. 125.

Although it is more than probable that they belong in the main to the Low-level series, perhaps not associated with clay through unfavourable conditions for its deposition, yet it is incredible to suppose them altogether untouched by subsequent fluviatile and æolian agencies. We are, however, unable to map Blown Sands or recent river gravels in this tract, there being no means of distinguishing them.

Between Kettleby Lodge and Barnetby Junction there are two patches of well-worn flint gravel making features in the sand tract. Sand is exposed to depths of from 6 to 10 feet in ditches and drains on the slope between Wrawby Mill and Kettleby Lodge. By the road from Kettleby Lodge to Wrawby, a few chains north-west of the Railway, reddish sand, with bits of flint in places, is shown. Low-level, red grey-mottled Clay under red sand was noticed at about 7 chains from the Railway. South of Kettleby Lodge a patch of gravel, of worn fragments, chiefly flint, occurs on either side of the high road; it is bounded by sand on every side but the south, where indications of the Low-level mottled Clay have been obtained. The Clay is surrounded by sand.

At the bottom of the letter *t* in the words Ket*t*leby Carrs, on the Map, grey and brown mottled Boulder Clay, containing worn fragments of flint and Chalk, is exposed in a ditch: it appears to be overlain by coarse pale grey sand with worn granules of Chalk and flint. South of this red-brown grey-mottled Clay was noticed in one or two places.

Between Kettleby Carrs and Westrim there is a large patch of sand with broken fragments of flint and gravel; it probably belongs to the Low-level series, as red-brown grey-veined Clay was ploughed on both sides of the Railway at the letters FOR in the words *GLAMFORD BRIGGS* on the Map.

There appears to be no intervening strip of Oxford Clay between the Low-level Clay and Chalky Boulder Clay south of the letters *Gorse Co* in the words *Gorse Co*ver on the Map.

The Low-level Clay was shown on either side of the valley between the words *Cover* and *BRIGGS*, on the Map; it is red-brown, grey veined, and stoneless; the band of Oxford Clay separating it from the Chalky Boulder Clay, on the south side of the Line, is scarcely more than 3 chains in breadth.

The sands and gravelly sand, upon which the upper part of Brigg is situated, seems to overlie the Low-level Clay on the south of the Station.

At the letter *e* in the word Westrim, on the Map, reddish-brown, grey mottled, rather plastic, Boulder Clay, with small flint fragments and sandy matter in it at about 3 feet from the surface, is shown in a ditch. The Clay is also exposed near the letter *m* of the word Westri*m*, on the Map.

On the slope south of the Railway, near Brigg Station, a small pit, about 4 feet in depth, shows brownish and yellowish-brown sand, with a gravelly surface of flint fragments, and containing small flint pebbles and occasionally pebbles of grit and (?) syenitic rock.

On the south of Woodbine Cottage a sand pit, 6 feet deep, but only exposed for 2 feet from the surface, shows light brownish sand of medium sized grains, with a seam of worn and unworn fragments of flint, and occasionally of chalk, at 18 inches from the surface.

The sand is somewhat loamy and contains bits of flint in the drain, on the north side of the Union House; a similar sand was dug into, in the foundations of the large house at the turning to Brigg Station. Near Redcome, and by School House Lane the sand is more like ordinary Blown Sand, being apparently devoid of stones, and of pale grey brownish or straw coloured tints.

Between Brigg Union House and the Station there is a patch of gravel, resembling the large patch on Wrawby Hill; it has been worked in a very large pit now converted into a garden; the exposures show rather small well-worn flint gravel and sand, near the surface.

This gravel is separated from the Wrawby Gravel, partly by Low-level Clay, partly by sand with bits of flint; so it must either rest directly upon Oxford Clay and be entirely surrounded by newer deposits of the Low-level series, or belong to the upper part of that series and rest on Low-level Clay. I have no means of proving either hypothesis. Again, if this is an outlier of the Wrawby Hill Gravel it would on the second hypothesis make that gravel not only more recent than the Chalky Boulder Clay but posterior to the Low-level Clay (compare gravel between Elsham Station and Wrawby, *infra*).

On the south of the high road to Wrawby, near the path to Woodbine Cottage, red-brown grey-veined Clay of the Low-level series is exposed in drains, on the lower part of the slope below the Wrawby Hill Gravel, an intervening band of Oxford Clay is also shown toward Wrawby.

At about half a mile to the east of Wrawby Church, on the north side of the lane leading to Carr Drain, a pit now for the most part concealed by rain-wash and grass growth has been excavated in reddish-brown and grey Clay, got out from the sides of the pit by spudding. A surface specimen of *Gryphæa dilatata* proves the vicinity of the Oxford Clay.

By the drain due east of Wrawby Church, on the west side of the high road, reddish and purplish-brown, grey-mottled, Clay, overlain by reddish sand and gravel, is exposed.

A short distance further north the mottled Clay is evidenced by the high road, and gravel is shown on the west of the road.

In Catchwater Drain, near School House Lane, on the east, red-brown mottled Clay is exposed, also in the direction of Little Carr Drain. North of Little Carr Drain, in Catchwater Drain, from 5 to 6 feet of reddish-brown, grey-veined, Clay, containing a sand patch in one place, rests unevenly on the Oxford Clay (with its broken masses of earthy limestone often containing *Gryphæa dilatata*) and is separated from it in places by an irregular impersistent gravelly seam.

At half a mile north of Wrawby Church (south of the letter D in the words Little Carr Drain on the Map), a ditch exposed reddish-brown Boulder Clay with numerous chalk fragments overlying chalky gravel and sand.

South of Elsham Station, on the west side of the high road, Little Carr Drain gives the following interesting section in descending order:—

	Feet.
Fine gravel and coarse sand, with small pebbles and subangular fragments of flint, chalk, and, occasionally, quartz - - - - - -	2
Red-brown clean Clay, splitting along even laminæ, the surfaces of which are generally coated with films of sandy matter - - - -	from 2 to 5

The Clay, where thickest, is exposed to the bottom of the drain, but it speedily attenuates westward, showing an underlying bed of gravel, similar to the uppermost bed.

The sudden thinning of the Clay in this section might reasonably induce one to think that it would be impersistent, wedging out, and so permitting the gravel and sand beds above and below to coalesce in one indistinguishable mass. This may be the case in the Barnetby valley and perhaps in other places; but in the district between Elsham Station and Brigg the Clay seems to be well developed.

The upper gravel in Little Carr Drain section makes a small mound feature on the north side of the Drain, on the west side of the high road. A pit in it shows about 6 feet of coarse and fine, sorted, gravel, with a strong dip, apparently quaquaversal. The gravel is composed of well-worn and subangular fragments of flint, chalk, and occasionally of Red Chalk; numerous serpuloid bodies occur in the sand, they seem to have been derived from a soft grey rock (? Neocomian claystone) of which a subangular fragment was found. The sand is also composed of worn materials.

From the gravel feature toward Catchwater Drain the Oxford Clay is concealed by sand in which bits of flint may occur. This sand is either the relics (from 2 to 4 feet thick) of the materials above the Low-level Clay, and so passes into gravel, or it is Blown Sand.

Sand covers the slope south of Elsham Station; in the ditches by the high road yellowish-brown and orange sand is shown to depths of from 2 to 5 feet. The age of these sands is exceedingly doubtful; although they have no doubt been much shifted by winds, the apparent association of gravel with them toward Worlaby, about Kettleby Lodge, and north of the letter *i* in the words Little Carr Drain, on the Map, would almost justify us in including them in the Low-level series.

Between the letter *n* in the words Little Carr Drain, on the Map, and the Railway east of it, grey and yellow Clay is exposed, resting upon grey and yellow-sand. As the Clay cannot be referred to any of the solid formations, and does not appear to be alluvial, we have considered it an exposure of the Low-level Clay.

Mottled Clay beneath sand is shown in a drain about 2 furlongs west of Elsham Station.

The chalk quarries by the side of the railway, three-quarters of a mile east of Melton Ross, show hollows filled with loam and rubbly chalk.

(*d.*) *East of the Ancholme, north of Elsham.*

Mr. Strangways has made the following observations between Elsham and the Humber, on the east of the Ancholme:—

Sand is shown in a drain at Bonby Hill.

Gravel is exposed in a drain between Bonby and Saxby.

Chalk gravel is visible in drains below Saxby.

Gravel is shown in a drain below Willow Heads and in drains below Grange.

In Horkstow gravel pit the stones are nearly all of chalk, and are well rounded; one or two foreigners (igneous).

In the drain by Horkstow Bridge Road sandy soil rests on red-brown Boulder Clay streaked with grey.

In Fulsoar Drain, at South Grange, South Ferriby, gravel is shown.

At the south end of South Ferriby there is an old sand pit.

Mr. Tripp's Well was sunk through about 15 yards of gravel.

The two last observations show the abrupt ending of the sand and gravel against the Kimeridge Clay bank at South Ferriby.

C. F. S.

On the Humber bank, near South Ferriby, there is a fine gravel, of chalk and flint fragments, exactly similar in appearence to, though differing in composition from, the gravels of the flats near Hibaldstow, Redbourne, and Waddingham. This gravel is, however, partially bedded in the lower part of the cliff, and it rests on Boulder Clay which in one spot appears to be intercalated with it, an irregular strip of red-brown Clay occurring in the gravel. The following detailed observations on this coast tend to show that the Low-level deposits are of newer glacial age.

On the Humber cliff, near South Ferriby, fine gravel, composed of angular and subangular fragments of flint and chalk, rubbly in places above, stratified below, rests on light red-brown Boulder Clay, containing bits of chalk in places; farther east dark brown gravelly matter forms a soil on the gravel which contains a band of Clay with bits of flint and chalk, apparently Boulder Clay; beneath this irregular tongue of Clay the gravel has a red loamy matrix and the occurrence of seams of sand in it here and there give it a well stratified aspect. Further east, near a little house, the Boulder Clay is represented by from 4 to 5 feet of brown loamy

Clay with stones, mostly small, of local rocks and various kinds of grit and quartz pebbles, &c., dispersed throughout with a tendency to weathering along lines resembling bedding. This Clay resembles the Boulder Clay at Cleethorpes and appears to pass into the stratified Clay.

Mr. Jukes-Browne describes parts of this section thus:—

Near the middle of the cliff, where it is about 12 feet high, the following is seen:—

	Feet.
Soil and weathered clay (3 or 4 feet) passing down into reddish-brown sandy Boulder Clay - - - -	10
Red-brown clay and light-coloured sand, interlaminated and resting on a layer of hard ripple-marked sandstone	1
Coarse gravel of large rolled stones, grey chalk and red chalk among them, seen for - - - -	1
Hard grey chalk on the beach below.	

This even superposition of Boulder Clay on an old sea-beach is particularly noteworthy.

Still further east the lower part of the Boulder Clay is a dull purplish or chocolate brown, stiff and unctuous, with small stones and numerous fragments of black shale probably derived from the upper beds of the Kimeridge Clay. At the east end of the section, where the cliff is about 20 feet high, this purplish clay was seen to pass up into the reddish clay of Hessle type by a gradual change of colour and without the intervention of any loam or sand.

(*e.*) *West of the Ancholme from Brigg northward.*

The small patch of Great Oolite south of Brigg seems to be overlain by gravelly and clayey materials of the Low-level series scarcely separable from the Alluvium by feature on the north and east.

By the path-road to Castlethorpe, north of Silversides, red-brown, grey-veined, Clay of the Low-level series is exposed in a ditch, and forms a strip of flattish land on the borders of the Alluvium; north-east of Castlethorpe a patch of gravel bounds the Alluvium; the Low-level Clay seems to come out from beneath it, crossing the road to Castlethorpe Bridge and extending for half a mile beyond it. The Low-level Clay is exposed under Alluvium in a drain at the letters *ck* in the words Brick Hills on the Map; it is also exposed at about 10 chains north-west of this drain.

The following are from Mr. Strangway's notes:—

Scotney Hill road. Gravel.

Borings in the Carrs—

Through 30 feet Gravel, clay, and limestones (Taylor).

Through 40 feet clay and gravel (Burton).

At Mickle Holme Farm there are two wells 21 and 17 feet deep; nothing but sand penetrated.

Winterton Holme Farm.—In the dyke three quarters of a mile east of the Farm, purple-brown clay with grey streaks, containing chalk pebbles, is exposed. A large boulder of Dolerite lay on the bank.

Winterton Brickyard (disused).—Reddish Clay, with grey streaks and containing pellets of Chalk, apparently 10 to 15 feet thick, of which 5 to 6 feet is exposed, is said to rest upon thin limestone. "This clay is said not to make good bricks on account of white checkers."

Winterton Holme, West House.—Clay 7 yards, on gravel.

C. F. S.

Mr. Jukes-Browne adds:—

Where the road to Winterton Holme crosses the Roman Road, a dyke shows dull reddish-brown Clay with a few stones, overlain to the south by sand and loam with freshwater shells.

A. J. J.-B.

Sand, Peat, and Alluvium of the Trent Valley.

Whether the valley of the Trent was connected at one time with that of the Witham, producing the insulation of the greater part of Lincolnshire, or existed as a wide estuary, one thing is tolerably certain, viz., that the valley-bottom consisted of sand (marine or estuarine). The sand was exposed for a period of sufficient duration to be drifted into dunes and mounds and wafted eastward up the slopes bounding the valley. The æolian drift probably became general during an elevation which drained the valley sufficiently to permit of the formation of a marshy soil, upon which trees would appear subsequently to have flourished for centuries. From partial inundations, unfavourable climatic conditions or other causes, the valley became unfit for forest-growth, and was tenanted by marsh vegetation, in which the trees decayed.

Throughout the period of forest growth the Trent was no doubt in existence, but its alluvial sediment never appears to have covered the Peat-land on its borders, although some feet below the present high-water mark.

Sand and Peat east of the Trent.

In the Frodingham district, and here and there in the Liassic area further south, Peat beds occur in the sand, suggesting the probability of the sands above them being blown, and those beneath being an alluvial or estuarine deposit.

In the lower part of Scotton Common, at about a mile West of Scotton Church a bed of Peat occurs on the surface, resting on greyish white sand.

West of Cleatham, by a plantation a mile and a half east of Scotter Church, buff and yellow sand with impersistent seams of peaty matter is exposed in a drain, resting upon from 1 to 2 feet of black Peat.

At half a mile west of Twigmoor, and at half a mile east-north-east of Ashby Grange the surface of the sand is peaty.

By the stream due south of the letter *e* in the words Brumby Warren on the Map the section is as follows:—

	Ft.	In.
Yellowish sand - - - - - -	1	6
Peat - - - - - - -	1	0
White and grey sand - - - - -	5	0

The easternmost part of the Frodingham Quarries extends as far eastward as the stream, near the north-western boundary of Gokewell Common, on the Map. In this part of the quarries, where the Ironstone is overlain by blue Lias Clay, the sand occurs in two beds separated by a stratum of Peat. The upper sand is buff and yellowish; it varies in thickness from 2 or 3 feet to 15 feet; this sand differs from the lower bed in colour.

The Peat bed crops out under the surface sand at about a quarter of a mile from the Gokewell stream, it forms a very marked band attaining to about 8 feet in maximum thickness.

The Peat contains fragments of birch stems and roots.

The lower sand bed is from 2 to 6 feet thick. It is greyish white in colour, and contains patches of peaty matter. The lower sand makes an

uneven junction with the Lias Clay which is exposed for about 4 feet at the termination of the deeper part of the section (forming a second narrower cutting through the bottom of the larger one). The sand fills pipes or cracks in the surface of the Clay and often contains very small fragments like broken Lias fossils. The base of the cutting at this part, for a foot or two, is shaly Lias Clay, but for 3 feet above it the Clay may be redeposited; the small fragments in the sand occur at the junction.

The impersistence of the Peat bed in the sand east of Frodingham is well shown in a long quarry on the south side of the Railway at about a mile from the station. In this exposure the Frodingham rock is overlain by about 8 feet of sand, in which at one spot a lenticular seam of Peat occurs, in a basin-shaped depression in pale buff sand; the overlying sand is brownish, and the Peat thins out toward the surface on either side.

The Peat bed seems to be at or near the surface for some distance from the Railway, on either side, at about a mile east-north-east from Frodingham Station.

Alluvial area east of the Trent.

Peat growth seems to have prevailed over a great part, if not the whole, of the alluvial area; but owing to the practice of artificial warping, it is seldom visible at the surface, and where it is visible its boundaries are either topographical, as on the north side of Bottesford Beck from three-quarters of a mile to a mile and a quarter east of East Butterwick, where the surface of a large field consists of unwarped Peat; or very indefinite in flaggy marshes, where no sections are to be seen and sand rises in low irregular mounds.

The peaty surface matter rests upon sand in most cases, and often renders the boundary of the sand very indefinite, as on the east of East Butterwick and Ashby Decoy as the sand is blackened by peaty matter, which may be merely a film.

In a well in the Trent Valley, at the cross-roads on Brumby Common, about 20 feet of Peat resting on clay, not penetrated at a depth of 20 feet, was encountered under 30 feet of sand; the underlying clay is probably Rhætic Black Shales. This would appear to be a lower Peat bed in the Trent Valley, as the surface Peat is almost invariably found to rest on sand.

Sand and Peat west of the Trent.

The relations of the deposits forming the flats on the west of the Trent are identical with those on the east, but the flat land being so much more extensive, there are much larger tracts of Peat at the surface unconcealed by artifical warp, as on Thorne and Goole Moors, west and north-west of Haxey. Mr. Cameron, who surveyed this district, notes a thickness of 20 feet of Peat on Thorne Waste, and on Hatfield Moor, east of Lindholme, 11 feet of it on gravel.

Mr. Atkinson tells me that "the surface of the peat where warping has not taken place is in many places only 2 feet above low water level in the Trent."

The following notes are by Mr. Cameron:—

At Gunthorpe a stratum of Peat, from 6 inches to 5 feet in thickness, was found in wells, under Warp, varying from 1 to 15 feet in thickness,

and resting occasionally upon Clay or Warp, but more frequently on sand. The water is hard, furring kettles, so that the water of the Trent is preferred to it and largely used.

In a well at Althorpe (old name Aletorp) no Peat was encountered, being apparently, as at Gunhouse Wharf, a channel of the river during the growth of the wood and Peat.

Much of the Peat is arable land, perfectly flat, and of a black or brown colour. Dotted about are hillocks of sand, on which are built the houses of the inhabitants.

Much of this deposit cannot now be seen, being buried under artificial or natural deposits of Warp, but enough remains in the wastes or moors, the black lands, and the submerged forest on the Humber foreshore, to show how densely wooded the country has been.

In the cultivation of the Peat land, much trouble and expense is caused by the great numbers of trunks and stumps of trees. Where a clearing has been effected these may be seen made into gate posts (chiefly oak stained black by the Peat) or they are stored for future use.

On the edge of Thorne Waste, works are erected for converting the wood into charcoal, used as manure. Attempts have also been made to produce paraffin, but apparently without success.

The wastes of heather-covered Peat may never perhaps be cultivated. In some places, indeed, they have been for a time under cultivation but have been allowed to lapse again into their original wild state.

Just west of Misterton and bordering the Peat a deposit of black clay with fresh-water shells, now drained and cultivated, indicates the site of a recent lake or tarn, a lingering patch of the watery morasses that formerly covered everything below high-water mark for miles around.

Here and there spots of low-lying wet land, neither drained nor cultivated, and overgrown by rushes, reeds and sedges, still continue as remnants of the marshes or morasses.

The North Car Drain is brown reedy earth on Peat. Idle Stop Drain shows the Peat to be thin, and to rest on red sand; Monkham Drain and the Snow Sewer are both on Peat, so is the Misson Level and the drains intersecting it.

At Haxey the Railway Station is on Warp, artificially deposited on an old floor of sand (Humber beds). In the Gunthorpe Drain, Haxey Gate, and West Stockwith, the Warp clay is seen.

At Ouston Ferry the Warp is 15 feet thick and is underlaid by Peat.

Ouston Ferry.—Seven inches of Warp is said to have been deposited between two tides, on the banks of the Trent at this place. [This and the following statement are on the authority of the ferryman.]

Six feet might be laid down artificially in three summers, this however, not constant, as the Warp is deposited unevenly, owing to currents in the water.

At Temple Belwood clay land made from the Keuper Marl comes down to the edge of the Warp, which has there been artificially laid down, on Peat. All drains of 3 feet on the clay lands reach the Keuper.

Further round on the east on the border of the Alluvium, at Froghall, Peat, 3 feet thick, with numerous roots and trunks of trees, chiefly oak, is found. Here the Peat has almost thinned out between a

large spread of sand on the one side and the Alluvial clay of the River Idle, on the other: under the Peat, is a soft unctuous blue Clay.

The Idle and the Don are now mere ditches, but their former courses are conspicuous in the line of brown Warp meandering through the black Peat-lands, or by sinuous troughs to be met with occasionally in the Sand.

A. C. G. C.

Alluvium and Warp.

The true Alluvium or flood loam of the Trent does not extend far from the river bank on either side; beyond its limits the flats are composed of a Peat bed or peaty soil on sand, but owing to the process of artificial warping (*i.e.*, conducting water charged with sediment through channels cut in the river bank to tracts previously surrounded by banks) the original Peat surface is seldom visible.

In a footnote to p. 38 of The History and Topography of the Isle of Axholme, by the Rev. W. B. Stonehouse, M.A., a reference to a paper by Ralph Creyke, *Trans. Soc. Arts, Vol.* 43, is thus given: "It is said that the practice (of warping) was first introduced about the middle of the last century on some land in the neighbourhood of Howden" (border of Yorkshire).

The formation of the Alluvium proper or natural warp by precipitation of sediment held in suspension by water overflowing the channel of the river explains the fact that from the Trent banks the ground usually falls very gently, merging into the bounding flats; for the heavier particles subsiding nearer the channel the materials spread by the waters would decrease in amount as they encroached on the flats, so that at a short distance from the bank a scarcely perceptible film might be thrown down on the Peat.

Mr. Cameron, who surveyed the area west of the Trent, furnishes the following notes:—

Much valuable land is made in the north-west corner of Lincolnshire and those parts of Yorkshire and Nottingham bordering the Humber and Trent by artificially warping the old "going land" (ancient warp), also the Peat and sand, a process by which the unprofitable soil is buried under fresh deposits of rich alluvial sediment, with which the waters of the Humber and the rivers flowing into it are heavily weighted.

Certain parts of the district, or particular farms, are enclosed by banks, the tidal waters are made to enter through floodgates and drains and to flood the surface, there to remain till the mud is deposited; the water is then drained off, the process being repeated at intervals until the required depth of soil is accumulated.

By this process land is raised 6 feet in three summers, or 2 feet in a year, the Warp not taking long to settle when the waters are

undisturbed by currents. Where, however, currents exist the Warp is deposited unevenly.

In the immense tracts of natural Warp, now arable land, the maximum thickness seems to be 40 feet, which has accumulated at no very distant date in some form of estuary.

Marling tends to consolidate Peat; lime and calcareous manures having a useful effect on mossy soil. Peat, when limed, produces white clover, daisy, and grass, where none grew before. Lint or flax grows well on Peat. Mossy soil is always thinnest where it lies on sand or gravel.

By the term "Marl" is here understood Warp, clay artificially or naturally laid on.

In artificial warping, if the land is too high to be reached by the warping drains, "Cart warping" or "Dry warping" is resorted to; for instance, where a sand hill can be warped all round, but not itself buried, the sediment that has been deposited round it is carted on to the hill itself; or an elevated patch of heather-covered Peat is transformed into arable land in the same way, tram rails being laid to the nearest clay flats.

A. C. G. C.

The processes of artificial warping have been by no means uniformly carried on in the Trent valley, some tracts being so thinly warped as barely to conceal the peaty substratum, others so thickly that Peat is not shown in the drains. The tendency of warping is to compress the Peat, so that irregular warping does not produce any appreciable inequality in the surface level as it would do were the substratum incompressable. The deposition of artificial Warp is also very uneven; on Mr. Peacock's farm (rather more than a mile from East Butterwick in the direction of Ashby Decoy), for instance, the Warp in the same field varies from 1 to 3 feet in depth.*

East of the Trent.

The natural Warp does not seem to extend far from the river bank; but, as it is impossible to distinguish it from artificial Warp at the surface, its boundary is very vague, even where sections are exposed by the cleaning out of drains.

In West Common North Drain, when cleaned out, the natural and artificial Warps were shown to rest irregularly on Peat, but were scarcely distinguishable the one from the other. The natural Warp does not appear to extend for more than 14 chains from the bank of the Trent at East Butterwick; from thence its boundary seems to run northward by Meerhole Clough and Car Dyke to points about a quarter of a mile east of Burringham Ferry and Boggard Hall, crossing the Doncaster and Barnetby line on the east side of Gunness Station. From Gunness Station on the inside of Amcotts Hook the natural Warp probably spreads, extending to about three-quarters of a mile from the river between Gunhouse and Grange.

At Neap House it may extend to 3 furlongs from the Trent bank; and it seems to constitute the whole alluvial flat from Flixborough Stather northward to Burton Stather, and also the Trent Ness flat, at the confluence of the Trent and Humber. Between Flixborough Stather and Burton Stather the natural Warp may be partly overlain by artificial

*For details as to the process of Warping, *see* the following papers in *Journ. Roy Agric. Soc.*:—P. Pusey, vol. iv., p. 295; R. Creyke, vol. v., p. 398; T. J. Herepath (with analyses), vol. xi., p. 97; J. A. Clarke, vol. xii., pp. 387, 371. Dry Warping is described by W. Edwards, vol. xi., p. 180. An analysis (by E. Hunter), of Warp from the bank of the Ouse at Goole, is given by Dr. H. F. Parsons, *Proc. Yorkshire Geol. Soc.*, N.S., vol. vi. (Pt. iv.), p. 229.

Warp, especially in the neighbourhood of a farm (not shown on the Map) east of Cottley Hall.

The natural Warp varies from brown loamy clay and brown loam to dark grey, drab, and grey and brown clay.

Near the mouth of the Trent and in the Humber Bank, between Whitton Channel and Pudding Pie Sand, chocolate-brown clay, marbled with grey, and evenly-bedded in places, is exposed; this clay is identical with the (newer glacial) Low-level Clay of the Ancholme valley, but it is not overlain by gravel and sand. It appears to be natural Warp, but if contemporaneous with the Low-level Clay it certainly cannot be regarded as ordinary Alluvium, although the flat surface beneath which it occurs is alluvial.

By the Alluvium, at the place where the stream on the north side of Flixborough emerges from its narrow channel, a very gentle slope is composed of alluvial clay and loam with fresh-water and land shells, mixed with tufaceous matter in places. The next stream on the north seems to have offected a similar deposit where it emerges from Burton Wood. Between the streams on the low tract flanking the Alluvium white tufa and orange and yellow tufaceous matter, indurated by ferruginous infiltration, conceals the sand subsoil.

In a stream course, about half-way between Alkborough and Whitton, from 2 to 3 feet of alluvial or rain-wash soil is shown; a piece of coarse black pottery was found in it. The stream-bed is composed of Liassic rock.

Peat and Alluvial Deposits of the Ancholme Valley.

The deposits of the Ancholme Valley are very difficult to classify, owing to the uncertainty respecting the age of part of the Low-level deposits. In the excavations on Island Carr it would appear that the Low-level Clay and its associated sand and gravel underlies the more recent Alluvium and Peat. These deposits no doubt occupied the Ancholme Valley, and were subsequently denuded and re-deposited; the chief difficulty presented by the district being the impossibility of ascertaining to what extent such re-deposition took place.

Thus, whilst the Low-level sand and gravel is clearly defined in sections showing its relation to the Clay, where this relation is not manifest they could not be distinguished from Alluvial deposits of more recent date formed from them.

After the deposition of the Low-level deposits the Ancholme flats, by elevation or other causes, appear to have been at least partially covered by wood growth or vegetation, which was in process of time invaded by the river, or submerged beneath an arm of the Humber Estuary; the clay, silt, and gravel then formed, being subsequently deserted by the waters, furnished soil for the growth of woods over the flat lands; in some cases, as pointed out by Mr. Atkinson, the size and nature of the trees point at least to centuries of this woodland growth, traces of which as the upper Peat bed cover so large a part of the surface south of Brigg. Through stoppage of drainage or depression of the area

the woodland became converted into a morass, from which it has been reclaimed by a thorough system of drainage. To Mr. Atkinson, the Engineer who superintends these works, I am largely indebted for valuable information respecting borings and sections in Sheet 86.

The Alluvium of the Ancholme consists of dark grey and brown clay and brown loam; north of Brigg its limits are easily definable; but south of Brigg the alluvial clay is by no means co-extensive with the flat ground, and it is frequently concealed by a peaty surface soil. Where the clay is either at the surface or so close to it that the peaty matter may be disregarded hypothetical boundaries between Alluvium and surface Peat have been drawn on the Map.

A narrow patch of Alluvium occurs by the Ancholme at the margin of Sheet 86. Brown alluvial clay is at the surface between Ings House and Caistor Canal, it is most probably continuous, under the Peat, with the main mass of alluvial clay at the surface, which extends northward from Green Dyke, near Wootham Hill, by Swing Bridge and Redcar Bridge.

From Low Bank, near Hibaldstow, southward, a flat tract, not separable from the Alluvium by level, and composed of fine gravel generally found upon the Low-level Clay, extends around the low features made by the Great Oolite rocks. A similar gravel flat occurs at the south margin of the Map (Sheet 86) near Waddingham and south-east of Old Mill.

The gravels of these tracts are chiefly composed of small fragments of local Oolitic rocks and of flint. From the flat tongues of gravel are traceable in the Inferior Oolite districts on the west, as west of Hibaldstow Lodge and west of Beanland Cover and Pyewipe Hall, and up the Waddingham Valley.

In the main we have had to describe the gravels of this tract with the Low-level Clay (newer glacial) series, and their irregular association with the Low-level Clay, and position, irrespective of present drainage lines, in places, as north of Hibaldstow, may justify this view; but to the stream-valley deposits extending west from the tract a more recent age must be assigned, and it is incredible to suppose that no re-deposition of the gravels between the Inferior Oolite districts on the west and the Alluvium on the east, took place, we have therefore drawn hypothetical lines connecting the stream-valley deposits with the Alluvium with which we may regard them as roughly contemporaneous, the parts of the gravel-flats within these lines being taken as redeposited.

South of Caistor Canal the Alluvium seems to consist for the most part of flat peaty soil, mixed, perhaps, with films of alluvial loam. The substratum is fine gravel, similar to that of the Waddingham valley, &c., but more largely composed of flint. The surface is frequently a peaty gravel soil, but alluvial matter has subsided upon it in distinguishable amount here and there, as by Owersby Drain and east of Old Mill, so that whether the surface of the gravel were a re-deposit or not it would be scarcely possible to map it separate from the true alluvial soil.

North of Wootham Hill the soil is black and peaty.

In the drain near Redbourne River Head Peat is exposed under alluvial clay.

On the south of Gadney a tree trunk, with stool 28 feet in length, and another nearly 20 feet long, was noticed in the Peat. Trees were also

noticed in the peat and peaty soil west of Ings House, near the junction of the Ancholme and Caistor Canals, on the west of Holme Hill, and by Green Dyke.

On Cadney Carrs the soil is for the most part peaty, the Alluvium consists of brown clay.

On Froghall Carrs, near South Bank, the soil is peaty in places; at about half a mile south of Froghall a trace of flint gravel was observed.

The surface of the Alluvium is peaty between Low Bank Drain and Redcar Bridge, and from thence southward to Ryecroft Hill, south of Newstead Old Causeway; by Black Bank; on either side of the road to Cadney; at about half-way between Newstead Priory and Sand Hill Farm; and south of Silversides, near Brigg.

North of Newstead Priory, the Alluvium is covered by black peaty soil containing bog oak.

For the following information I am indebted to Mr. Atkinson, of Brigg:—

Section disclosed in digging clay on Island Carr, between the river and canal, north of the high road on the west side of Brigg.

	Ft.	In.
Soil and Peat - - 1 ft. to	1	3
Alluvial clay with remains of freshwater plants - - - 3 ft. or	4	0
Peat - - - about	0	6
Boulder clay resting on the bed of limestone		

In the same brick-yard, probably in enlarging the excavation above described, an interesting discovery was made; it was thus described by Mr. Atkinson, in a letter to me, in April 1884:—

"I heard the other day that they had found same old wood in the brick-yard below my office. I found an ancient roadway, made of riven oak planks laid edge to edge, transversely. Under these are trees and branches (some yew) laid lengthwise. At the ends of the oak planks holes have been made and stakes driven through to secure them. The planks are all *in situ* and do not seem to have been disturbed in any way. The road is 6 feet below the present land level, it rests upon and is *pegged into* a stony deposit. This deposit changes into red boulder clay, 50 yards to the south and into sand about the same distance north.

Above the road there is 5 feet of soft alluvial clay, with sedges; and above that the surface Peat, 1 foot thick. These are altogether *undisturbed.*"

(From a letter dated May 4th, 1884.) "The surface of the road is about 11 feet above low water in the Humber, and *13 feet below* high water. It is about 3 feet below the present drainage level of the Cars.

Within living memory the Cars about Brigg used to be under water three months in each year.

Roman remains are found in the surface Peat."

He says in the letter previously quoted "I have just lately cut through the ancient road (said to be Roman) between Redbourne and North Kelsey. It has been carried on oak piles; but the roadway was in the *upper* Peat. This Peat bed contains remains of gigantic oak trees, which must have been centuries old.

The drift below the Alluvium was not level, and so the Peat which grew thereon varies considerably in thickness. Thus in Alcock's brick-yards, just south of the M. S. & L. Railway, and westward of the old River Ancholme, there is 15 feet of clay and then 3 feet of Peat."

Mr. Atkinson considers that "the road (discovered at Brigg) is on the horizon of the lower forest-bed of the Ancholme level.

Nothing metallic has been discovered near the road, but there has been found . . . . a bit of round bone, with a 'mortise' sunk half way through, and three small holes bored through each side."

At 500 yards from the site of the old road in a south-easterly direction,* "a most interesting boat of a very primitive type was found," in 1886, lying "almost at right angles to the old channel of the River Ancholme."

"The upper edge of the boat was 2 feet below the surface of the ground at the bow and 3 feet 7 inches at the stern."

"The boat is made out of one huge log of oak, which has been dug out or hollowed," the length is 48 feet 6 inches, and depth 2 feet 8 inches at the bows, and 3 feet 1 inch to 3 feet 4 inches at the stern.

"The beds passed through in digging are in the following order, beginning at the top:—

Surface soil.	
Peat and forest bed.	
Brown alluvial clay.	With remains of sedges.
Dark bluish-grey alluvial clay.	
Peat and forest bed.	
Drift.	

The upper edges of the boat were slightly above the junction of the two clay-beds." Remains of Diatoms, all marine forms, were identified in the brown clay by Edmund Grove, A.M. Inst. C.E., "In a sample of the grey clay Mr. Grove found acicular sponge spicules but no trace of Diatomaceæ," . . . "the bed of the Humber is cut in these clays, and for some distance from that river up the Ancholme valley the clay is covered with a bed of recent Alluvium or Warp." "The present Alluvium or 'Warp,' with which the Humber is now so highly charged, is of quite a distinct character from the two clays below the upper Peat." "The trunks of enormous oak trees mixed with the remains of yew, birch, and hazel are frequently found in the upper Peat." "Roman remains are only found in the upper Peat." In the paper from which the above quotations were taken, the remains of the Roman road in the Upper Peat crossing the Ancholme Level in North Kelsey parish are also refered to.

* From "Notes on an Ancient Boat found at Brigg."—By Alfred Atkinson. *Archæologia*, vol. 50 (10 pp.), 1887.

The bones found in the excavations on Island Carr were indentified as follows by Mr. E. T. Newton:—

Red deer (*Cervus elaphus*)	scapula, tibia, piece of antler, left ramus of lower jaw, vertebræ.
Ox	ischium.
Sheep	humerus.
Dog	pelvis, scapula.
Human	lower jaw; all molar teeth have been lost during life.

Lower Peat.—In the above the upper Peat is spoken of in contradistinction to the lower Peat bed of the Ancholme Valley, which has been encountered in places, but from its depth beneath the surface, apparently from 8 to 16 feet or so, it is difficult to obtain authentic information respecting it. I am indebted to Mr. Atkinson for the following observations respecting this bed :—

"In building Castlethorpe Bridge over the Ancholme we found it about 9 feet below the surface. In deepening the old river near Coal Dyke End it was met with at about the same depth. An old man who worked there has often told me that the hazel-nuts, acorns, 'oak-apples' (galls) &c. were as fresh as if they had only been there a few months. Antlers were frequently met with.

Mr. Finny, Chemist, Brigg, has a pair of antlers found in Clark's brick-yard, near the Railway, at a depth, it was said, of 12 feet. That would probably be in the lower Peat."

On Broughton Cars rather peaty clay was encountered at about 26 ft. 9 in. from the surface in sinking a well through:—

	Ft.	In.
Top Peat	0	9
Blue clay	20	0
Tough silty clay	6	0
Harder clay, rather peaty	5	0

There is no evidence to show that the Peaty clay is representative of the lower Peat bed; it is, however, possible. In a neighbouring well on Broughton Carrs no Peat was encountered below the surface. The lower Peat is exposed under Alluvium in the drain near Redbourne River Head.

According to Mr. Strangways :—

At Thornton Bridge the Alluvium and gravel average about 3 feet. In one place the section consists of:—

	Ft.	In.
Alluvial soil	1	0
Gravel	1	3
Boulder clay.		

Lower down the Beck there is an exposure of—

	Ft.	In.
Alluvium	2	0
Gravel	0	3
Shale.		

C. F. S.

On the north side of the high road to Bigby, between Skegger Beck and the Barnetby and Lincoln Railway, a freshly-cut drain, about 4 feet deep, gave the following section:—

Buff, and yellowish sand, in parts irregularly overlain by peaty matter.

Coarse grey sand (apparently containing comminuted fresh-water shells) with peaty matter here and there at the bottom of the drain.

Patches of flint gravel occur in and under the sands.

On the south side of the Railway at the letter *B* in the words Glamford *Briggs*, on the Map, a stream bank shows alluvial clay upon yellowish sand and flint gravel for 5 chains.

The alluvial clay is used for brick-making at Brigg, where there are three brick-yards, and also on the north side of the Barnetby and Doncaster line, east of Thornholme Priory.

On Broughton Carrs the Ancholme Canal and ditch beside it show, dark grey upon brown, alluvial clay.

On the west of Planker Dyke the surface of the Alluvium is peaty in places, near its junction with the Blown Sands.

Between the Decoy and Thornholme Priory the surface of the Alluvium is peaty and its boundary indefinite, owing to the admixture of the bordering Blown Sand in the surface soil.

In the drain to Birdhouse Clough west of Decoy, peaty matter and trees occur in sand, which may be a recent wind drift.

Mr. Strangways gives the following section of a well at the Farm on Winterton Carrs:—

Clay - - - - - - - 15 yards
Gravel under.

He also notices the occurrence of a forest-bed under the Alluvium, at the Humber bank below Ferriby Hall.

"Buried trees under about 8 feet of Warp clay." "Very little gravel under the trees."

Lacustrine deposits.—Traces of lacustrine deposition, consisting of white and whitish consolidated loam, or levigated mud, with recent fresh-water shells, are met with in the following places:—

By Little Carr Drain, east of the high road to Elsham, forming a small patch, apparently filling a hollow in the surface of the Low-level deposits, bounded or concealed, on the east, by sand, probably blown over the lower ground.

In a drain on the east of Priestland Cover, apparently associated with sand.

In a stream bank, in a narrow extension of the Waddingham gravel tract, flanked on the east and west by sands, at nearly a mile east from Waddingham Church.

A whitish tufaceous deposit is visible by a tributary of the Hibaldstow stream, at about half a mile south of Scawby Station.

Blown Sand.

At the foot of each of the great escarpment features, which are also the leading geological lines in North Lincolnshire, we find extensive deposits of Blown Sand upon the low ground.

At the foot of the Wolds.—About Clixby, Caistor Nettleton, Owersby, and Claxby Moors there is an extensive tract of sand, which is nowhere found to conceal the Cretaceous escarpment, although it has doubtless formed the

source from which the patches of sand on the Wolds east of Caistor and north of Cabourn Mill have been blown.

In the Barnetby valley the sandy deposits have been irregularly blown over the surface, so that no distinction between the wind drift and the deposit *in situ* can be made with certainty. Again, the sands of Brigg appear to have been drifted by wind in places, as, near Redcome. On the north of Wrawby the lower ground at the foot of the Wolds, extending to South Ferriby and bounding the Ancholme Alluvium on the east, is largely composed of Blown Sand, which, however, cannot with any degree of certainty be separated from the sandy and gravelly deposits, which it partially conceals.

Oolitic Escarpment.—The Blown Sand, piled up at the foot of the Oolitic escarpment, north of Kirton, has been drifted eastward, entirely covering the steep slope of the escarpment near Twigmoor Warren, and between Crosby and Santon Warrens, and extending irregularly down the dip-slope of the Inferior Oolites to Scawby and Broughton.

Blown Sand extends entirely across the Inferior Oolite area from Santon and Risby Warrens to Appleby Carrside, Broughton Carr Side, and Wressle Wood, where it is bounded by the Alluvium of the Ancholme.

Liassic area.—It is a curious fact that the Sands prevail north of Kirton and Scotter, where the Boulder Clay districts terminate. In the Boulder Clay districts, sand, associated either with gravel or Boulder Clay, occurs, and in or near many of the valley bottoms sandy soils conceal the solid rocks; but, except on or near the borders of the Trent Alluvium, no extensive deposits of sand are found. Between Ashby, Bottesford, and Emmanuel Bridge, and near Ashby Grange, there are some indications of Gravel, or Boulder Clay, having once extended over the area; or of the sands being partly of glacial origin. Near Ashby the soil is loamy, and occasional foreign pebbles are found on the surface, and a small boulder of grit was noticed in a field between Ashby Grange and Bottesford Beck.

The Liassic rocks are to a great extent concealed by Blown Sand, which appears in the first instance to have been an estuarine deposit in the Trent valley and in the valley at the foot of the Oolitic escarpment. In the Trent valley the natural and artificial Warp, or Alluvium, rests upon a bed or soil of Peat, beneath which sand is generally found; the sand patches in the Alluvium of the Trent are inliers of this sand stratum, but they have been heaped up into mounds and dunes by the action of the wind; and the sands which occupy a low tract on the eastern borders of the Alluvium of the Trent have also been sifted by æolian action and spread over high land, as on Scotton Common, near Messingham, Yaddlethorpe, and Flixborough, Burton, Alkborough and Whitton.

South of Flixborough Old Church the sands cover the slope of the Lias escarpment; also in places near Scotter.

At the foot of the Oolitic escarpment from Thealby and Bagmoors southward to Kirton Lindsay the lower and major part of the Lower Lias dip-slope, as well as the Middle Lias features, in the lower part of the escarpment, are covered by Blown Sand.

East of the River Trent.—In the north of Brumby Common the surface is very marshy; Blown Sand forms low hills and mounds and occurs in a labyrinth of irregular patches of swampy ground, apparently consisting of Peat and Warp; the surface is covered by rank marsh vegetation and the topography of the Map is very defective.

About a mile from Boggard Hall there are long banks of sand, by and near drains; also on the south side of the road to Burringham Ferry, which, though doubtless erected as warping banks, in most cases, present here and there, as on either side of the road to Burringham Ferry (at about a mile and a quarter east of the Trent) so undisturbed an appearance as to suggest inliers of sand cut through in warping operations rather than artificial embankments.

At about a mile west of Ashby Decoy Farm two small banks of sand on either side of the road appear to be *in situ*.

The very irregular occurrence of the sands in the Alluvium, on the east of the Trent, in which, here and there, they form low mounds, and the extensive Blown Sand tract which conceals the junction of the Keuper, Rhætic, and Lias rocks, suggest æolian derivation from an extensive estuarine deposit, which, except in the vicinity of the river, is found to underlie the Peat and Warp.

It would, however, be impossible to distinguish at the surface this sand in flattish districts from Blown Sand derived from it.

West of the River Trent.—On the west, as on the east of the Trent, a considerable area is covered by sand, occurring in low-lying tracts very little above the level of the Peat and Warp land in places, and abutting against the Keuper Marl hills of Misterton, Epworth, and Crowle. It has been blown upwards over the higher ground at Haxey. The sand also occurs on the Carrs, or flats, in inlying patches surrounded by Warp on Peat.

On this, as on the other side of the Trent, it is quite impossible to say whether the sand on the low grounds, where not piled in dunes or low hills by æolian action, is an original and undisturbed estuarine deposit or not. The marked feature round the Marl hill of Haxey, over which sand had been continuously blown, induced Mr. Cameron to draw a line separating the sand mantling over the slope from that occupying the low-lying tract at its foot, and this line has been shown on the Map, as it has some agricultural significance, but it must not be taken as a geological boundary.

Mr. Cameron says:—

The sand land on the elevated parts, having a subsoil of Keuper (red clay), is considered 20*l.* per acre better than the so-called "Grey Sand" land of the levels.

The sand of the low moorland tracts is called "grey land"; it is often shown resting on the Keuper Marls.

Crailsound.—A good deal of light sand occurs on a Marl subsoil in the higher parts of the district. The sand is often merely a thin surface soil, and appears to have been blown off the adjacent lower land. On the edge of the Peat at the Monkham drain the Keuper appears to be only thinly covered with sand.

Compacted, ferruginous sand is found round the base of the high lands at Park. A shallow section of yellow and silver-grey sand, very dense, is exposed in drains to a depth of about 5 feet.

In the Upperthorpe sand-pits, and the waste land adjoining, sand has accumulated to a considerable height in dunes, strongly suggestive of wind action.

By the road from the New Torne (Thorne) river to Woodhouse yellowish sand is shown.

Pan, or hard compact sand of a red colour, the particles being held together by an oxide of iron, is found beneath the Peat of Sandhill.

Three feet of sand is shown on Keuper at Ealand going to Tetley. Yellow and white sand, in the banks of the Double River, rests on Keuper.

White sand on red clay or Marl is visible at Canal House.

The following section was disclosed in Mr. Robinson's brick-yard Crowle Wharf in 1882:—

	Ft.	In.
Clean red sand	2	0
Red and green clay (Keuper)	6	0

A. C. G. C.

North of the Humber.

Glacial Beds.—Boulder Clay occurs along the north shore of the Humber from Red Cliff to Hessle and from thence spreads north-eastwards over the eastern slope of the Wolds, as will be described in the next chapter. West of Red Cliff and Melton, the Boulder Clay is overlain by later superficial beds of the Humber, and is not seen at the surface within the northern part of Sheet 86. It has however been proved by borings, and it probably underlies the whole of the alluvial area referred to. The thickness of the drift varies considerably in short distances, and consequently the old surface of the Trias was much more uneven than the present surface of the country.

Gravels.—Gravel occurs near North Cave and Everthorpe, and again from Brantlington southwards to the Humber. At North Cave the gravels, which are stratified and rounded, are composed almost entirely of Lias fragments; and the great quantity of specimens of *Gryphæa incurva* contained in them is very remarkable; in some of the pits between North and South Cave this shell is so abundant as to warrant their being called a "Gryphite gravel."*

Along the ridge between Ellerker and Brough similar coarse gravels occur, but here most of the included fragments are from the Oolite; and it is curious to observe in both these cases that the rocks from which these gravels are derived outcrop at the spot or lie immediately to the north.

A pit near Brough well shows the irregular character of this gravel. It consists mainly of Chalk and Oolite; but there are some foreign pebbles, as well as fragments of ironstone, coal, and decayed wood. The sand lies in wavy beds, presenting a very marked appearance in the lower part of the section. The upper part has at one time been used as a burial place, as numerous bones as well as entire human skeletons and urns with burnt bones, have been dug out.

The slight hollow in the Oolites east of Ellerker is filled with a deposit of Sand and Chalk-gravel, which is 4 feet thick in the shaft at Woo Dale; but increases to 7 feet in the boring near Elloughton, where it rests on 13 feet of clay with flints, and to 26 feet in a well south of that village, where it rests on clay. The section here is—

Well, a quarter of a mile south of Elloughton.

	Ft.	In.
Sand	26	0
Clay	14	0
Stone	6	0
Clay	4	0
Total	50	0

Whether the upper of these clays is Boulder Clay is not certain, although it probably is, and in that case the 6 feet of stone would be the Kellaways Rock. About Brough these sands and gravels are probably thicker, but the sections are not reliable. At Melton the sand and gravel die out, but at Red Cliff, on the Humber bank, there is an isolated patch resting on stiff purple Boulder Clay.

* *See* Tate and Blake: The Yorkshire Lias, p. 69.

Besides the above there is a curious deposit of chalk-gravel, on the edge of the hill at Everthorpe, which has been cut through by the railway, exposing a good section showing that this gravel has been deposited against an old bank of the Middle Lias, and extends that feature about 200 yards further to the west, causing a deceptive appearance of the outcrop.

Fig. 6.

Diagram showing extension of the Middle Lias feature by Chalk Gravel at Everthorpe.

Warp and Lacustrine Clay, Sand and Gravel.

These deposits cover much of the country near the Humber, the sands making slightly rising ground, above the general flat surface.

The beds have a thickness varying from 25 to 90 feet, although in some cases, especially near the edge of the rising ground, they thin away to less than this.

The sands have a thickness varying from a few inches to 10 or 15 feet. They consist of clean yellow and white soft sand, which is often ferruginous, and causes the water issuing at their base to be highly charged with iron. The sands are frequently interstratified with thin seams of peat and black earth, containing freshwater shells and plant remains, which give to the surface the character of a black sandy mould.

There is usually a thick deposit of laminated clay below the superficial sands, and in the vicinity of the Humber a bed of Peat.

This Peat thickens to the south of Goole, and is probably the same as that exposed in the banks of the Humber at Melton, South Ferriby, and Whitton.

Alluvium, Modern Warp, and Peat.

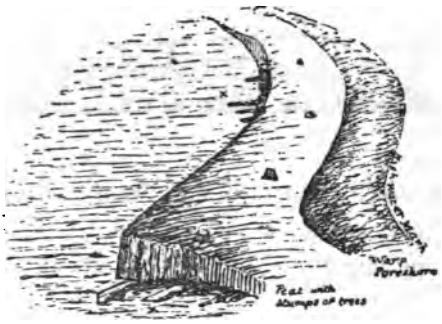
Along the sides of the principal rivers, such as the Ouse, Derwent, and others, there is a strip of modern alluvium, forming a narrow tract below the level of the surrounding country. This, as it approaches the Humber, becomes merged with the modern warp or tidal alluvium of that estuary, which latter is continuous with the ancient warp so that no lines can be drawn between them. At Brough there are 18 feet of this clay.

Intimately associated with these deposit is a bed of peat, which varies in thickness from a few inches to as much as 20 feet. It

is well exposed in the Humber at Melton below high-water mark, and has been met with in several of the sections (given in the York and Hull Memoir). This peat contains the stumps and trunks of great numbers of trees, the former being firmly rooted in the sands, and exhibiting the marks of tools with quantities of waste chips, thus showing that these beds have been covered up since the advent of man.

Fig. 7.

Sketch of the Humber-Shore at Melton, showing Peat with Stumps of Trees.



Level of Low (× Indicates tree-stumps in the Peat.)

CHAPTER XVII.*

SUPERFICIAL DEPOSITS—*continued.*

EAST OF THE WOLDS.

The great variability of the Drifts in different parts of Sheet 86, and the extreme uncertainty as to their correlation, make a geographical classification the only one which can be adopted in this district. The Wolds form a division between two Drift-covered areas, which apparently have little in common. East of the Wolds there are Inter-glacial Marine Gravels; both Boulder Clays are uniformly purple and chalky, when unweathered; and there is no marked valley-erosion between the two Boulder Clays there seen. West of the Wolds Mr. Ussher's account shows that no marine shells have been found in any part of the Drift; and that there may be two Boulder Clays of very different lithological character, separated by a period of great erosion. Towards the south-eastern margin of the area Mr. Jukes-Browne considers that this distinction of lithological character is again recognisable (*see* pp. 170, 171).

The following account of the maritime area east of the Wolds is largely taken from the "Geology of Holderness." †

Boulder Clay.

Owing to the uncertainty of the correlation, the Boulder Clays will be described together, whether above or below the Marine Gravels. The lithological differences between the two divisions are so slight, and there is so much difficulty and uncertainty in tracing the beds, even with the nearly continuous cliff section of Holderness, that it is evidently quite hopeless to attempt to correlate isolated inland sections by their lithological character. The differences also, often disappear when the beds are traced laterally, and are largely due to chemical changes and weathering.

Although the greater part of the area east of the Wolds is covered with Boulder Clay, there are very few good sections in the interior; and the following notes include all which can be clearly seen in Sheet 86, and show anything but a few feet of Boulder Clay of the common type. For the mapping of the country there was abundance of evidence in the deep ditches, except where the land is low and marshy.

The greater part of the southern half of Holderness, being very low, shows few good exposures, except in the cliff, and at Hessle and Kelsey Hill. Boulder Clay, weathering reddish with ash-coloured joints, is mentioned as occurring at the bottom of the excavations for the Albert Docks, Hull, separated from a lower bed of purple Boulder Clay by a seam of sand.‡ Similar beds were seen in the new Alexandra Docks. Numerous well-borings penetrate to the Chalk, but the details are generally of little real

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* By Clement Reid.

† Memoirs of the Geological Survey. Geology of Holderness and the adjoining parts of Yorkshire and Lincolnshire, by Clement Reid. 1885.

‡ J. C. Hawkshaw: "The Construction of the Albert Dock," &c.—*Proc. Inst. C.E.*, vol. xli. p. 492.

value. Some good exposures were laid bare in the cuttings for the Hull and Barnsley Railway, where it entered the Wolds, though nothing was seen but weathered reddish Boulder Clay resting on Chalk, or only separated from the Chalk by a foot or two of rubble or chalky gravel. In places the Chalk was glaciated and broken up to a depth of several feet.

The only other sections of interest north of the Humber are those at Hessle and Kelsey Hill. Having been taken by Mr. S. V. Wood as the type of his "Hessle Clay," these will be described fully; but it may be at once observed that neither of the sections can be accepted as showing the original character of the Boulder Clay. In each case the clay has undergone great alteration and weathering.

The Hessle sections show Boulder Clay overlying mammaliferous gravel, but overlapping it and resting directly on the Chalk where the cliff becomes higher. At present the exposures are bad, but Prof. Phillips has published an account of them, as seen in 1826, in which he gives several sections, and describes the Boulder Clay as a thick bed of brown and blue clay, with chalk, flints, granites, gneiss, syenite, limestone, porphyry, hornstone, and coal. He also found what seemed to be an elephant's tusk.* Similar clay can still be seen both here and at several spots in the neighbourhood. Mr. Cameron observed that in the low cliff of North Ferriby there is a purple chalky Boulder Clay, the upper portion of which weathers red.

The Boulder Clay overlying the gravel at Kelsey Hill ballast pit, near Keyingham Station, on the Hull and Withernsea line, is so much weathered, though nearly 13 feet thick, that for a long time I felt uncertain whether it was anything but rainwash. The common occurrence of flints in it seems, however, to show that originally the deposit was a chalky Boulder Clay; but all or nearly all, calcareous matter having been dissolved out, it is now simply a stony loam or brick-earth. South of the Farm the Boulder Clay sinks almost to the marsh level, and in the railway cutting it has become purple and chalky. A short distance north there is no Boulder Clay on gravel hills over 50 feet in height, but no definite system can be traced in these irregularities. Another Boulder Clay, in this neighbourhood only known from borings, underlies the Gravel, and seems to rise to the surface around Keyingham. These sections will be again referred to in the description of the Marine Gravels.

Under the Humber there is evidently a considerable thickness of Boulder Clay, though none of the borings yet made have shown the full depth of the old, probably pre-glacial, Humber Valley. Mr. Kelsey, the engineer to the North-Eastern Railway Company, has kindly communicated to me a series of borings across the Humber. (*See* Appendix II., p. 217, &c.) They prove that Boulder Clay, interstratified with sand and gravel, reaches a depth of at least 83 feet below the present level of high water; and, judging from the dip, there will be a still greater thickness in the old channel, but borings Nos. 5 and 6 were not continued sufficiently far to settle the depth to the Chalk.

On the south shore of the Humber a well made some years ago at Killingholme Coast Guard Station penetrated through Warp and Boulder Clay to a depth of 107 feet without reaching the Chalk. Here, again, the old channel seems to have been found.

A section seen in the low cliff of South Ferriby is the only exposure of Boulder Clay on the south shore of the Humber. It corresponds closely with that seen at North Ferriby, and exhibits Boulder Clay separated from the Chalk by thin ripple-marked flaggy sandstone. From this point eastward Boulder Clay forms a belt separating the Chalk Wold from the Humber flat, clearly showing that the ancient Humber Valley was not only deeper but wider than the present one, and was subsequently partially filled with Drift, through which the present river is excavating its channel.

At Barton-on-Humber drainage works and wells showed good sections of purple chalky Boulder Clay of the ordinary character; and similar, though less chalky, clay irregularly overlies the Chalk in the large pits

* Phillips: "Notice of the Hessle Drift as it appeared in sections above Forty Years since."—*Quart. Journ. Geol. Soc.*, vol. xxiv., p. 250.

west of the town. The lower part of the little Dale which runs west-south-west into the Wolds is also filled with Boulder Clay; a well about a quarter of a mile from Mount Close has been sunk through 15 feet of clay before reaching the Chalk. This old channel filled with Drift seems to be continued under the town, towards the Humber, though there is now no trace of it at the surface. From the descriptions of the well-sinkers and builders the old Dale is very well defined under the Drift, and must have steep sides like the Wold Dales of the present day. At the junction of King Street and High Street there is, according to Mr. Westaby,—

	Feet.
Clay and Chalk (Boulder Clay) - - - -	30
Gravel - - - - - - - -	33
Chalk.	

Probably this is about the centre of the channel, for other wells in the town show the Chalk much nearer the surface.

South of Barton Boulder Clay stones are scattered over the Wolds to a height of about 150 feet, but there is nothing to show positively whether the Boulder Clay has been denuded, or whether no more Drift ever lodged there. The Chalk is often glaciated to a depth of several feet, and foreign stones have been forced into it.

The ditches around Barrow and Goxhill show numerous exposures of a purple Boulder Clay, but the only good section is in a sand-pit about a mile north of Barrow Church. Here a very chalky Boulder Clay overlies the sand, appearing to follow the slope of the hill; the greatest thickness seen is only 3 feet, though wells in the neighbourhood show that in places it becomes much thicker. The Boulder Clay at the surface in the low lands seems usually to overlie the fossiliferous gravel; but at the edge of the Wolds, near Thornton and Ulceby stations, Boulder Clay rests directly on the Chalk, perhaps rising from beneath the gravels. Nearer the Humber the intervening gravels are often missing, the two Boulder Clays coming together, as they apparently do on the coast. Many of the borings show nothing but clay above the Chalk, though others show two beds of Boulder Clay separated by gravel.

Boulder Clay of the same character is found all through the low lands between Halton and Grimsby, but there being only ditch sections, with the exception of a small pit at Great Coates, it is unnecessary to give further details. Along the edge of the Wolds, however, the relations of the beds can be well observed, and Boulder Clay can be seen both over- and underlying the fossiliferous gravel. The surface Boulder Clay of the low lands overlying the gravel thins out about a mile from the Wold edge; and as the gravels rise, patches of an older Boulder Clay are found to lie between them and the Chalk. The outliers at Ulceby may belong to one of these, though in this instance the absence of the gravels prevents the true age being definitely determined. However, in the large valley of Croxton, through which the railway passes, the evidence is perfectly clear: for not only is Boulder Clay seen in ditches at the bottom of the Dale, but on digging in the centre of two pits in stratified fossiliferous gravel very characteristic chalky purple Boulder Clay was found. It is also interesting to find that this Boulder Clay is, in its lithological character, quite indistinguishable from the newer chalky and purple Boulder Clay which overlies the Gravel a short distance further east. The sections being near the bottom of the valley show conclusively that the Dale existed before the deposition of this lower Boulder Clay, and that its deepest erosion is unconnected with the Gravel Period.

Near Brocklesby, Limber, and Irby there are apparently other outliers of the same Boulder Clay, though the want of open sections prevents their relation to the Gravel being definitely proved. South of Laceby the Gravels suddenly thin out, the two Boulder Clays come together, and there is nothing to show whether it is the upper or lower one which rests directly on the Chalk.

Returning to Grimsby, some of the most interesting sections were exposed during the main drainage works, which were going on during my

stay there. These showed two Boulder Clays, purple, chalky, and exactly alike, separated sometimes by a mere line of division, sometimes by gravelly sand in which fragments of the inter-glacial shells were found. Though the sections were examined almost daily, not the slightest difference could be detected between the two Boulder Clays, either in their matrix, or in the included boulders. There was a seaward dip in the beds, so that the line of junction between the two clays on the north was a good deal below the level of high water; but to the south, as the upper Boulder Clay rose above high-water level, its character gradually changed; it lost much of its calcareous matter, and joints with a blue and green mottling on their faces appeared in it. This weathered Boulder Clay was lately visible in a sand-pit close to the Roman Catholic Church, where it wraps round a mound of the fossiliferous inter-glacial sand. Being fully exposed to the weather, the Boulder Clay has changed into a stony brick-earth.

Brick-yards near Grimsby and Cleethorpes show deep sections of the Boulder Clay, sometimes with a line of division in it. One of these pits, near Cleethorpes, has been dug to a depth of nearly 20 feet below high-water, but shows only a chalky purple Boulder Clay, like that of the cliff, but showing no divisions. At another, about half a mile south-east of Grimsby station, a large collection was made of stones from the Boulder Clay. Among them was a block of Rhomb-porphyry, a very marked and characteristic rock from the neighbourhood of Christiania, and also numerous boulders of the Halleflinte and Porphyrite. Many of the other rocks are also probably Scandinavian, though they have not at present been definitely traced. They included red Flint (Danish), Gneiss, Mica Schist, Garnetiferous Hornblende Schist, hard Sandstone or Grit, Carboniferous Limestone, Diabase, and several varieties of Quartz or Felspar Porphyry.

Great caution is necessary in this district in the collection of Boulder Clay stones; for enormous quantities of Scandinavian and Russian rocks are brought annually in ballast from the Baltic ports, are used for road metal, and find their way on to the fields in manure. They are usually, however, Basalts and Garnetiferous Gneiss of a quite different character from any yet found in the Boulder Clay.

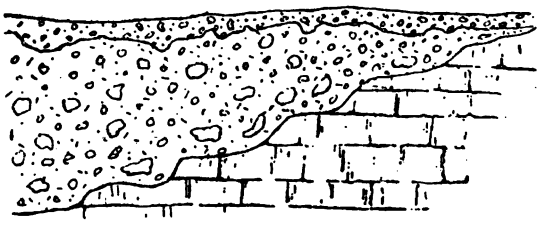
Between the Wold and the salt marshes near Tetney and Fulstow the belt of Boulder Clay becomes narrower; the Gravels have died out; and, there being no sections, it is impossible to say whether only one or all of the Boulder Clays are represented. Well sections seem to show that the Drift is banked against a very steep slope, if not an actual cliff of Chalk.

C. R.

The following notes by Mr. Jukes-Browne refer to the "Older Glacial Drift" on the Wold and in the Valleys at the south-east corner of the Map:—

Older Glacial.—A mass of Chalky Boulder Clay caps the Chalk Wolds, east of Binbrook in Sheet 84, and its northern prolongation just crosses the south edge of Sheet 86 between Swinhope and Wold Newton.

FIG. 8. *Section in Gravel Pit west of Wold Newton Church.*



No sections of this clay were exposed at the time of my visit, though several old pits existed from which it had apparently been dug for claying

the lighter soils; but I found a deep excavation for gravel, by the side of the road, one mile due west of Wold Newton Church. The section in the centre of this is as below:—

	Feet.
Brown soil full of flints in pockets	2 ft. to 4
Coarse gravel, composed of flints and lumps of Chalk in a matrix of sand and fine gravel	40
Chalk with uneven surface.	

From this depth of 40 feet the Chalk rises steeply on either side in a series of rough steps, and the workmen said that the gravel died out in a distance of about 20 yards to the southward; the longer axis of the trough thus excavated out of the Chalk runs from north-west to south-east. The Gravel is bordered by Boulder Clay on the south and on the east.

Large masses of chalk occur in the gravel; one such mass, with flint-bands nearly vertical, and now half-quarried away, must have measured some 8 yards in length, according to the workmen's account, the part left is 10 feet wide by 8 in height. Another mass, 8 feet broad, was just being exposed at the time of my visit (June 1883); while near the entrance there was a third long tabular mass of chalk, about 20 feet long and passing into re-assorted white marl; but the greater part having its bedding so little disturbed that it might have been *in situ*. A vertical section near the entrance was therefore as follows:—

	Feet.
Brown soil and flints	1
Bedded chalk with seam of marly clay	2
Sandy gravel enclosing a lenticular layer of hard chalky sand, laminated and contorted	4
Coarse gravel, loose and unstratified	6 +

The seam of dark grey marly clay at the base of the Chalk was from 2 to 6 inches thick, and exactly like the bands which so frequently occur in the Chalk with flints. It would seem therefore that a mass of chalk together with a clay band had been quarried out of the hill, and embedded in the gravel without disturbance of its bedding or destruction of the clay. This could only have been accomplished if it were frozen into a mass of ice.

Some of the flints found here are very large, being 2 feet square and 8 inches thick, but such lumps could have been obtained from certain flint bands in the Chalk of the vicinity, and the whole of the materials are evidently of local origin. The phenomena are altogether such as would be produced by the action of coast-ice acting upon a frozen shore of Chalk; though doubtless some of my colleagues will suppose them to be equally well explained by land-ice.

Newer Glacial—The boundary line of the newer Boulder Clay enters Sheet 86 exactly at the south-eastern corner, and tongues of it run for some distance up the valleys in which the farms of Cadeby and Beesby are situate. Thence the boundary runs to Hawerby, where the manner in which the clay is banked against the Chalk is proved by the following information furnished by Mr. Harness, whose house stands about 150 yards north-east of the Church; he states that in his father's time a well was sunk in the yard to a depth of 52 yards through clay, finding only a poor spring at that depth, which ran dry in the summer time; the clay occupies the surface as far as the churchyard, but Chalk is found below the Church, so that within 150 yards of the boundary line there is a depth of more than 150 feet of Boulder Clay.

But, although this steep slope, or cliff, of Chalk now forms a boundary line for some distance northward, yet there is ample

evidence that the Boulder Clay originally surmounted it and covered the still higher ground which forms the ridge between Hawerby and Wold Newton. An outlying patch of this enveloping sheet of clay still remains on the very highest tract north of Stocks Furlong Cover where the height above O. D. is given as 382 feet. Again, though bare Chalk is found for some distance along the eastern slope of the hills north of Hawerby, yet near East Ravendale there are two places where it is still continuous from the base of the slope in the parish of Ashby to the very highest ground in Ravendale Field, a thick sheet of clay still covering this ridge and sending two long tongues southward one along the high ground and one into the valley which comes down from Wold Newton. From the mapping it is quite clear that all these patches and tongues formed parts of one continuous mass which originally enveloped this tract of ground, and that the existent boundary lines are the result of subsequent detritive agencies which have stripped the clay off the steeper slopes and laid bare the underlying Chalk. There is no evidence, however, that this mantle of clay ever extended farther than about 2 miles westward of the old cliff-line, or to heights greater than 400 feet.

The following are notes of sections and exposures in the tract above described:—

At a brickyard three-quarters of a mile south of East Ravendale Church, the working face (1883) showed from 2 to 6 feet of reddish-brown loam with seams of small flints and pebbles, evidently a wash from the slopes above. At the base of this, in some places, there is sand with springs of water. It rests on a greyish-blue stony clay, quite different from the ordinary Hessle or Purple clays, but certainly a Boulder Clay, and having a good deal of fine silt in its composition; this has been dug for 10 feet. The proprietor (Mr. Willis) had trial holes made on the slope above and east of this face, finding a red-brown marly clay full of stones "like that at Cleethorpes." I was also informed that westward (near the road) there are 3 or 4 feet of red loam overlying peaty sand and sandy gravel full of black-stained flints. At the kiln there is solid Chalk, probably a boulder or dislodged mass, for the cistern at the house above was dug in a "mixture of sand, gravel, and chalk stones" part of a bed of sand and gravel which has been formerly dug in the next field to the northward.

Another intercalated bed of sand runs through East Ravendale and is dug in a sand pit by the roadside west of the Church. The sand is full of small pebbles and interstratified with layers of sandy gravel; the bedding undulates but is not contorted; the pebbles are like those in the Boulder Clay and pieces of grey shale (? Kimeridge Clay) are frequent. In the ditch by the side of the road, north of this pit, there is hard brown sand passing eastward into stiff sandy loam, full of stones and boulders, brown mottled with grey along the lines of shrinkage; it is, in fact, a very sandy form of Boulder Clay.

At West Ravendale there are two large mounds or hillocks of loamy sand and gravel with brown Boulder Clay bedded between and around them.

Between the farm half a mile north-east of West Ravendale and the copse called Bacon Holt a new drain had been made (1883), exposing a reddish-brown Boulder Clay below a variable depth of sandy loam, but in one place a dark ash-grey clay without stones took the place of this loam. This drain runs into the deep ditch leading to Bacon Holt, and here there is yellow brown sandy loam (5 feet) overlying dark red-brown clay mottled with grey and full of grains of sand (3 feet seen).

The Boulder Clay which occupies the Ravendale valley forms a continuous strip and passes beneath the alluvium of the Hatcliffe valley. It has been removed from the steeper slopes near Hatcliffe, but an extraordinary mass of glacial deposits occurs to the south of Hatcliffe, bedded into an old valley which was evidently the pre-glacial continuation of that which passes by Swinhope and Thorganby. This old hollow is filled with beds or masses of clay, loam, gravel and sand; the two latter forming banks and mounds of considerable size, while brown clay and loam appear to occupy the lower ground, but the whole arrangement is so confused and irregular that the mapping is little more than guess-work.

At Mr. Haxby's house half a mile south of Hatcliffe I was informed that the well was sunk 27 feet through sand without reaching the bottom of the deposit and this seems to be part of a bank stretching completely across the valley. In the hollow to the west of the house there is brown Boulder Clay full of stones; on the other side of this "bottom" there is a steep hill rising some 50 feet above it and seemingly composed of sand, which has been dug at the northern extremity. This hill is crowned by a fine tumulus not indicated on the Ordnance Map. Another deep hollow separates this eminence from the Chalk hill to the westward. South of this an isolated mound (? of sand) rises out of the loamy flat; but the slopes near Gunnerby seem to consist of a red-brown loamy clay, some old excavations west of that farm being known as the "clay holes." The hill-top south-west of Gunnerby is capped with sand, which has been dug in several places, but the eastern, southern, and western slopes of the hill consist of Chalk. Clay and loam border the watercourse to the west at a much lower level to a point about 6 furlongs south-east of Gunnerby, where the valley contracts into a very narrow passage.

The mounds of Drift above described have completely blocked the ancient course of the stream between this point and Hatcliffe, forcing it to excavate a new channel passing through the Chalk hills, which originally formed the western slopes of the old valley. This new cut will be described on a later page, but the contrast between the aspect of the different sections of the valley north of Thorganby is very striking and interesting.

The valley below Croxby Pond is also blocked by a large mound of Drift, and brown Boulder Clay has been dug at the south-east corner of the Pond, which appears to occupy the place of a lake naturally created by this barrier, but enlarged by an artificial dam.

Between Beelsby and Irby the covering of Boulder Clay is less broken up by subsequent erosion. It rides over the ridge near Wellbeck, fills the valley on its western side, and rises again to cover the high ground by Beelsby and Irby Holmes. Evidence of the pre-glacial contours is found by observing the rapid rise in the base line of the clay from the valley bottom opposite Hatcliffe Manor House to the top of the hill east of Beelsby. The Hatcliffe valley and its continuation northward to the Moats near Irby, being evidently in existence before the formation of the Boulder Clay, while the valley in which Beelsby lies and the gorge which the modern stream has cut through the ridge north-west of Hatcliffe Top are as clearly the result of Post-glacial erosion.

In the road-cutting half a mile south-west of Beelsby Church the usual red-brown Boulder Clay is seen, and thence its base rises gradually till it crosses the road near the farmstead nearly a mile from the church. The boundary then runs northward to Beelsby Top Farm, but is concealed by a long patch of Blown Sand. The height of the ground here must be nearly 400 feet above O.D., and there is no sign of Boulder Clay anywhere to the westward, so that I am inclined to think that the clay never extended much farther in that direction.

At the pond by Beelsby Top Farm there is a clean, brown, loamy clay, but in the field to the south-east an open grip shows stiff mottled clay of the Hessle type, with a few stones. Thence the same clay caps the high ground northward, between Beelsby and Swallow.

A. J. J.-B.

Gravel, Sand and Loam.

Though it has been impossible to make two divisions on the Map, the Gravels belong to at least two types. There are fossiliferous Gravels—generally marine—showing a cold, but scarcely arctic climate, and no clear evidence of ice-action. There are also coarse unfossiliferous Gravels, often inextricably mixed with the Boulder Clay. These latter have already been partially described in Mr. Jukes-Browne's account of the Drift in the Wold Valleys near Ravendale. The few remaining patches in this Map occur at Scartho, Barnoldby, Waltham, and Holton, but none of them are now worked; and as gravel is brought long distances from Laceby, they would appear to be of little economic value. Borings prove the occasional occurrence of another bed of gravel, lying on the Chalk, as in other parts of Holderness, but this bed is not seen at the surface.

Clean laminated clay has been worked at the Brick-kiln between Barnoldby and Waltham. At the time of my visit this section was very obscure, though the laminated clay appeared to be a bed in the Boulder Clay. There is nothing to show on what horizon it occurs.

The inter-glacial beds are very curious, being often banked against the old cliff, which forms the eastern edge of the Wold. They consist principally of Marine Gravel, but, in places, are of fluviatile or sub-aërial origin.

On the north bank of the Humber, at Hessle, is the well-known Gravel originally described by Prof. Phillips, and considered by him to be Pre-glacial. The most striking feature of this neighbourhood is the steep slope of the Chalk towards the Humber, forming what is commonly called Hessle Cliff, though it is by no means vertical. On this lies irregularly the mammaliferous Gravel, covered and overlapped by Boulder Clay.

The section in an overgrown pit by the side of the line, just west of Hessle Station, shows at the south-west corner,—

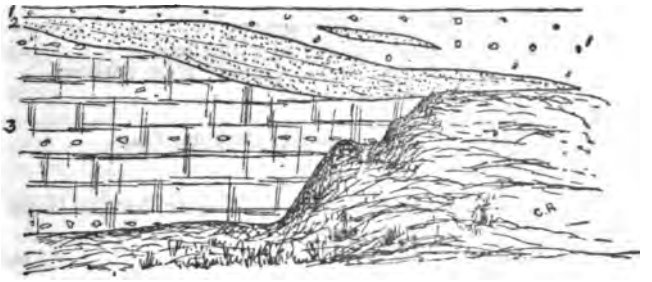
	Feet.
Purple Boulder Clay, weathering with greenish joints, many small fragments of Chalk, but few large boulders	10
Bedded sand with Chalk, looking very like an old "run of the hill"	?
Chalk.	

About 100 yards north, and close to the line, the section is,—

	Feet.
Boulder Clay as before	8
Bedded sand	0½
Chalk rubble	4
Chalk.	

Here the surface of the Chalk has risen considerably. The cuttings further west are now much overgrown, but the sections are similar to the above, the Chalk having a steep slope to the south.

Fig. 9. *Chalk-pit at Hessle.*



1 Boulder Clay. 2 Sand and gravel. 3 Chalk.

The diagram, Fig. 9, represents the north side of the large pit still further west. It shows Boulder Clay overlapping the Gravel, and resting directly on the Chalk; and also that there is not only a north and south slope of the Chalk, but also an east and west irregularity, probably an old channel connected with the Humber. In this or the adjoining pit bones of *Elephas primigenius*, *Rhinoceros*, *Equus caballus*, *Cervus*, and *Bos?* have been found; but no marine fossils are yet known, though the deposit is a long way below the level of the old shelly gravels with which it is often correlated.

From these details it will be seen that we have really nothing by which to fix the age of the Hessle Gravel. It lies on the Chalk, and is covered by a Boulder Clay; whether another underlying Boulder Clay has been denuded there is no positive evidence. What is the age of the overlying Boulder Clay we cannot say; it may correspond with any of the divisions on the coast, or with a division unrepresented there. Prof. Phillips' reference of the Hessle Gravel to a Pre-glacial period may turn out, with fuller evidence, to be well founded, though, as far as they are yet known, the fossils do not appear to support this view.

The marine Gravel forms a very important horizon in the Drift, as it distinctly lies between two masses of Boulder Clay, though the overlying clay has often been denuded.

North of the Humber, the exposures border on the flats a few miles east of Hull. Going eastward the first to be reached are a number of sand-hills lying between Hedon Haven and the Humber. Into one of these the stream has cut, forming a low cliff facing the Humber for nearly a mile, but never rising over 30 feet above high water. This is the well-known section of High Paull mentioned by Phillips and Prof. Prestwich; but since they wrote it has been sloped and built over for the Battery, and cannot now be examined.

The fullest account of the appearance of the cliff before it was hidden is that given by Prof. Prestwich,* who describes the section as showing sand with but little gravel, containing the same shells as Kelsey Hill, but in fewer numbers and more broken. This sand reposed on an irregular surface of grey clay; but the clay containing no boulders or fossils, he could not feel certain about its being Boulder Clay. Subsequently, in digging below the base of Paull Cliff, Mr. T. J. Smith soon found the clay to become stony, and the specimens he sent to Prof. Prestwich had the

* "On the Occurrence of the Cyrena fluminalis, together with Marine Shells of Recent Species, in beds of Sand and Gravel over beds of Boulder Clay near Hull." —*Quart. Journ. Geol. Soc.*, vol. xvii., p. 446.

ordinary aspect of Boulder Clay. The section measured by Prof. Prestwich was :—

		Feet.
Cliff section	Soil and silty gravel	8
	Sand and gravel with shells	12
	Sandy dark-coloured clay without stones	6
Section obtained by digging at the foot of the cliff.	Clay with stones (Boulder Clay).	

Further east Mr. Cameron noted a pit-section near Newton Garth showing—

	Feet.
Small gravel, with marine shells, much coal, and various foreign pebbles	7

and also another pit on the south side of Boreas Hill in similar beds. Numerous other hills south of Hedon rise through the Alluvium to a height of about 25 feet, but none of them show sections. About Ryhill the Gravel forms a considerable spread not exceeding 25 feet above mean tide. A pit bordering on the Marsh showed—

	Feet.
Sand and gravel with numerous shells	9

On the north side of the railway the land becomes much higher, at Kelsey House exceeding 50 feet, and Gravel forms an extensive spread bordering on the marsh, and overlapped irregularly by Boulder Clay. Many years ago a ballast pit was opened in this hill, and worked so extensively that it is now a quarter of a mile long. This is the typical section of Kelsey Hill so fully described by Prof. Prestwich and Messrs. Wood and Rome; but not having been worked for some years, great part of the pit is now overgrown. However, at one spot a clear face of about 12 feet of much weathered Boulder Clay with small stones can be seen overlying the Gravel. The Gravel rises about 35 feet above the marsh level; and to test its thickness Prof. Prestwich and Mr. Smith had a boring made from the bottom of the pit expecting "to find the base of the gravel at a depth of 10 or 12 feet; whereas, after penetrating with difficulty to a depth of 36 feet, always in the gravel, but the lower bed more argillaceous, the work had to be abandoned. These borings, at Kelsey Hill gave,"—

	Feet.
Sand and gravel with shells	4
Larger gravel	16
Smaller gravel	8
Larger gravel in grey loam (Boulder Clay ?)	8
	36

From this it would appear that the Gravel must be upwards of 60 feet thick at Kelsey Hill, probably as much as 80 feet.

The Gravel is false-bedded and shingly, with beds of sand; and Prof. Prestwich noticed in it pebbles of limestone with scratches more or less obliterated, proving that in part it was derived from an underlying Boulder Clay, though in this place the lower Boulder Clay must be much below the sea-level. Fossils are common, and one of the most noticeable peculiarities of this locality is the extraordinary abundance of the fresh-water *Corbicula fluminalis* mixed with the marine species. Even now this shell may be picked up in hundreds scattered over the floor of the pit and in the ballast of the line.

More recently another closely adjoining pit has been opened to provide ballast for the concrete at the Alexandra Docks, and for the new railway. This pit was being worked so fast that the sections varied from day to day. In May 1884 it showed at the north end a perfectly clear face of boldly current-bedded shingle and sand of about 40 feet, without any trace of Boulder Clay. On the west side, also about 40 feet high, and close to Kelsey House, a purple, chalky, Boulder Clay overlies the Gravel, resting most irregularly on it (*see* Fig. 10, p. 184). This disturbance is probably, in part at least, subsequent to the deposition of the Boulder Clay; for a fresh-water alluvial deposit in one place fills a basin in the Gravel, lined with Boulder Clay, and is apparently contorted with it. This Boulder Clay sweeps down towards the marsh both south and east of Kelsey Hill farm, its base descending from 50 feet above the sea to about 20 feet in a quarter of a mile.

In both pits the Gravel has been worked till water is reached, but the same shingly current-bedded character is found throughout. The stones are principally flint and chalk, with many foreign rocks derived from the Boulder Clay, but no large boulders. Derivative Jurassic *Ammonites* and *Gryphæa incurva* also occur. Among the stones are many blocks and pebbles of Chalk bored by *Pholas*, showing that in places the sea must have cut into bare Chalk and not Boulder Clay.

The fossils are like those of the abandoned pit, but there are naturally slight differences between different parts of the same hill. It is interesting to note that Dr. Jeffreys' list from the old pit contains several species not found by the Survey; and the Survey list, principally from the new pit, contains several not found by Dr. Jeffreys. The slight differences in these adjoining pits are quite as great as are found on opposite sides of the Humber, or even between the Gravels of one extremity of Holderness and the other.

From both pits mammalian remains have been obtained; but, unfortunately, many of those found in the earlier workings were not preserved, and the new pit yields fewer than the old. The bones in the collections of Mr. Freeman (presented to the Geological Survey), Mr. Mortimer, Messrs. Lucas and Aird, and the Hull Museum, belong to *Elephas primigenius*, *Rhinoceros leptorhinus*, *Bison priscus*, *Bos primigenius*, *Cervus tarandus*, and *Trichechus rosmarus*, but no small mammals are yet known. Only one or two indeterminable fragments and some fish vertebræ were found in the course of the Survey. This, however, is no test of their abundance, as the whole of the collection from the new pit was made during a few hours, and the sand was not sifted for teeth of voles or fish. A full list of the fossils from Kelsey Hill will be found in the Holderness Memoir. The discovery of the Walrus at Kelsey Hill is noteworthy, for at the present day this species seldom strays far from the margin of the ice. Its occurrence is in keeping with the somewhat boreal character of the marine mollusca. The few land-mammals are not characteristically arctic, for the reindeer has lived as far south as Scotland within the historic period.

About half a mile from Kelsey Hill, in the north-east continuation of the same Gravel, there are two small pits; one, not far from Gospel Hill showing a patch of Boulder Clay overlying the Gravel. These yielded several species of mollusca corresponding with those of Kelsey Hill. Still further north-east, at Rea Hill, near Ridgemont, the Gravel sinks, and is apparently overlapped by Boulder Clay.

Southward, Keyingham is built on the Gravel, which here rises to a height of 65 feet, though overlapped within a short distance by Boulder Clay. South-west of Keyingham the Gravel reappears, skirting the marsh, and only reaching an elevation of 25 feet. A pit due south of St. Phillip's Cross has yielded *Buccinum undatum*, *Ostrea edulis*, *Cardium edule*, *Mactra*, sp., *Tellina balthica*, and *Corbicula fluminalis*, the last shell being much scarcer than at Kelsey Hill, only a mile distant.

Crossing the Humber at Hull, Marine Gravels reappear on the south side near Barrow and Goxhill, forming a belt which stretches for 10

miles along the foot of the Wolds. The first section reached is a small pit half a mile north-north-east of Barrow Monastery. Here there is—

	Feet.
Soil - - - - - - -	2
Boulder Clay, very chalky, apparently following the slope of the hill - - - - - -	0 to 3
False-bedded chalky sand, with a few small stones; no shells observed - - - - - -	7+

A pit a few yards higher up the hill shows only sand without Boulder Clay. The absence of shells in the above section is unusual, but is probably due to the constant shifting of the sand. In other pits seams of fine unfossiliferous chalky sand sometimes alternate with shelly gravel.

From this point to Littleworth the Gravel is overlapped or cut out by Boulder Clay; the upper Boulder Clay sometimes resting directly on the lower one. That the Gravel is not so disconnected as would appear from the Map, is, however, shown by numerous wells on the Barrow and Goxhill road. For nearly a mile these pierce the upper Boulder Clay, and derive their supply of water from the Gravel, which yet makes little show at the surface.

South and east of Littleworth the Gravel is exposed along the course of the Beck, and overgrown pits show that it must be of some thickness. The first open section is a small pit close to the rail, a quarter of a mile north of Thornton Station. Here false-bedded gravelly sand is dug to a depth of about 8 feet, and broken shells can be found throughout. The species obtained were *Cardium edule, Cyprina islandica, Mactra subtruncata? Pecten islandicus? Tellina balthica*, and *Balanus*, sp. Another pit close to the Station shows 12 feet of fine sand, with a patch of small gravel at the top, but it is much overgrown. A pit close to the stream west of Long Looks shows sand and false-bedded chalky gravel of Boulder Clay stones, with rolled pebbles of loam and marl. All the Gravels in this neighbourhood show the influence of strong currents, and appear to have been deposited as constantly shifting banks.

In a pit near Ulceby Station there is about 9 feet of gravelly sand and loam, the lower part passing into false-bedded chalky and carbonaceous sand. North-west of the station a deep and long ditch exposes chalky Boulder Clay, rising from beneath Gravel, and resting immediately on the Chalk. On the east side of the stream the Gravel appears to pass under an upper Boulder Clay.

South of Ulceby the 100-foot line (there are, however, no levelled contour lines yet in Lincolnshire) sweeps into an old submerged valley; and in this sheltered arm of the sea, as we should expect, there is a marked improvement in the state of preservation of the fossils, and at last we obtain evidence of comparatively still water. A section in Brocklesby Park, just outside the shelter, shows only gravelly sand, with much-broken shells, including *Cardium edule, Cyprina islandica, Mactra subtruncata, Tellina balthica*, and *Dentalium entalis*. But a small pit, a mile further west, near the rail, and not far from Croxton, shows a decided change, whole shells being abundant, and delicate species preserved. With the assistance of Mr. A. W. Raven I dug through the sand, and reached Boulder Clay in two adjoining pits, the section in the upper one being as given below:—

	Feet.	
Soil - - - - - - -	1	
Well-worn sandy Gravel with shells - -	3	12
Sand with fewer shells - - - -	7	
Boulder Clay (purple and chalky) - - -	1	

It is interesting to find Boulder Clay beneath the Marine Gravels, not only in the open districts, but even in a deep valley like that of Croxton.

A full list of the shells obtained at Croxton is given in the Holderness Memoir. The fauna is essentially the same as that of the Kelsey Hill and

Laceby pits, with the addition of a single specimen of a very thin *Tellina*, apparently *T. tenuis*, and a portion of *Cytherea chione*. Both are species unknown elsewhere from this horizon. The *Corbicula fluminalis*, of which three specimens were found, is at present unknown from any other locality in North Lincolnshire, though abundant at Kelsey Hill. The abundance of *Scrobicularia piperata* and *Bissoa* (*Hydrobia*) *ulvæ* shows the proximity of areas of tidal mud, though the bed in which they are now preserved is clean sand.

At Kirmington, a mile south of the last section, a still more marked change takes place. On a high-lying, gently inclined surface of the Chalk and Boulder Clay an outlier of the shore-deposits of the old sea has been preserved. These consist of *Scrobicularia* warp, very like that now forming between tide-marks in the Humber, marsh peat, and well-worn flint-shingle. The elevation above the sea is apparently about 80 feet, but there are no levelled heights in the neighbourhood to guide one. Pits on the north side of the village show the best sections, that at the brick-yard giving—

	Feet.
Well-worn beach-shingle, principally flint, but a few large white quartzites	10
Laminated warp, *Scrobicularia piperata*, *Bissoa ulvæ*, *Tellina balthica*, *Cardium edule*, *Mactra subtruncata*, *Mytilus edulis*, and abundance of *Foraminifera*	10
Peat, consisting almost entirely of reeds	0½
Warp with *Bissoa ulvæ*	0 to 1
Sand	6
Chalky gravel, not pierced (from the information of the brick-makers).	
	27

The shingle is systematically worked off the Warp, and is also extensively dug in a pit on the other side of the road. As is necessarily the case where coarse gravel has been rolled about and deposited on soft clay, the shingle rests on an eroded surface of the Warp. The Warp is similar to that of the Humber, and contains, like it, in certain seams abundance of *Scrobicularia*, *Bissoa* and *Tellina balthica*. Of the other species we have only the young. *Tellina balthica* is always the thin-shelled estuarine form. This thoroughly agrees with Mr. H. B. Brady's remark about the *Foraminifera* collected at the same time, that "the species and the appearance of the specimens alike indicate a starved shallow water fauna."

The Peat Bed is a most unsatisfactory deposit to examine. It is composed entirely of reeds; at least nothing else determinable could be found in it; no seeds, no wood, no moss, and no elytra of beetles, such as peat ordinarily contains. It does not appear to be a drifted deposit, as the underlying bed is full of small roots; neither does it necessarily show any great change of level, for brackish-water lagoons full of reeds often form behind shingle beaches, and their surface may be several feet below high water of the sea outside, though it cannot be below the level of mean tide. Reeds may also grow out of water a foot or two in depth.

Beneath the Peat there is another impersistent bed of Warp full of *Bissoa ulvæ*, showing alternations of estuarine and fresh-water conditions. The sand beneath, owing to water being reached, could only be examined to a depth of 5 feet; but the brick-makers state that it is 6 feet thick, and rests on gravel, the lower part occasionally containing shells. There is, however, nothing to show whether these are fresh-water or marine, or whether the statement is correct. The part exposed was ferruginous, and contained no trace of either chalk or fossils; it had evidently lost its calcareous matter by solution.

On the other side of the little valley that runs through the middle of the village of Kirmington, there is also clean laminated clay, which in the cellars at Mr. Frankish's house is 10 feet thick, and rests on sand from which water is obtained.

Around Kirmington Vale there is also sand and sandy loam, which may be either a modification of the Warp, or of the accompanying Sand. There is no clear section.

Still higher up the Dale there is an outlier of Gravel, consisting of rolled Chalk, slightly worn flint, and a few foreign pebbles. This is probably a valley deposit, of the same age as the Inter-glacial Beds, and it is worth careful searching for mammalian remains. Unfortunately I could never find the men at work to inquire whether any have been found.

Leaving the Croxton and Kirmington fiord, we pass the open-sea deposits of Brocklesby, and soon reach another inlet. This is much less interesting, for it appears to have been more open and exposed to the run of the sea. It has two entrances separated by an island of Chalk. At the mouth of the southern one, near Keelby Grange, there is an overgrown pit showing 15 feet of small Gravel and Sand, with abundance of shell fragments. The species obtained, 18 in number, all occur at Kelsey Hill and Laceby; there are no fresh-water species among them, and it is doubtful whether the upper part of this wold valley was occupied by a river, as was the case with the larger fiord at Kirmington. The marine shells found near Keelby do not show the influence of brackish-water, for *Scrobicularia* and *Hydrobia ulvæ* are missing. Even littoral species, such as *Littorina* and *Purpura* are absent. The beds at the only pit which yields many fossils must, however, have been exposed to the scouring action of the tides. The more sheltered area around Limber, next to be described, deserves careful examination for relics of a land and fresh-water fauna.

The Mollusca found at Keelby were as follows:—

- Anomia ephippium? *L.*
- Astarte borealis, *Chemn.*
- Cardium echinatum, *L.*
- ——— edule, *L.*
- Corbula gibba, *Olivi.*
- Cyprina islandica, *Lam.*
- Donax vittatus, *DaC.*
- Mactra solida, *L.*
- ——— subtruncata, *DaC.*
- Ostrea edulis, *L.*
- Solen siliqua? *L.*
- Tellina balthica, *L.*
- Venus gallina, *L.*
- Dentalium entalis, *L.*
- Buccinum undatum, *L.*
- Nassa reticulata, *L.*
- Pleurotoma turricula, *Mont.*
- Trophon bamffius, *Mont.*

Near Limber Nursery Boulder Clay appears from beneath the Gravel, but everywhere else in the neighbourhood the Marine Beds overlap the Boulder Clay, and rest directly on the Chalk. Great Limber is partly on Gravel and partly on Chalk, the Gravel lying in a valley, and having its limit generally well-defined by a sharp rise of Chalk. The town Gravel-Pit yielded a few shell-fragments.

South-east of the village a brick-yard shows the following section:—

	Feet.
Soil and loam	6
Blue Warp	15
Pan	1
Sandy loam	1
Buff sand	5
Sand (bored)	9 or 10
	37 or 38

Similar laminated clay, 4 yards thick, is said also to occur at the cross roads near Limber Schools, though it is apparently hidden by Gravel. The abrupt rise of the Chalk at Limber brickyard is very curious; for one of the cottages belonging to the pit is on Chalk, while not 80 yards away, on the same level, there is at least 37 feet of Sand and Warp.

The Warp was searched for shells and microscopic fossils, but nothing whatever could be found. Probably it is the same Warp as that at Kirmington, and the absence of Foraminifera is due to dissolution of the calcareous matter. On close examination it is seen to be full of race, concentric iron stains, and incipient ferruginous concretions. It seems to be a general rule in all formations that where this structure is found any

calcareous fossils will be dissolved away; the two changes, solution of the carbonate of lime and oxidisation of the carbonate of iron, generally going together.

South of Limber a long strip of the Gravel has been mapped as running up Fox Dale, but it is very doubtful whether this is entirely correct. For half a mile south of the Irby road there is certainly worn gravel, but the higher part of it may be merely blown sand and rain-wash lodged in the bottom of the valley.

About half a mile north-east of Great Limber Cover there is a curious section showing—

Soil and sandy gravel	0 to 4½	feet.
Boulder Clay, with Chalk and foreign stones, mostly small	5 to 0	
Pockets of pebble-gravel.		
Chalk with flints.		

The upper gravel is apparently part of the outlier mapped, but what the nests of pebble-gravel belong to is not clear. Near the southern end of the same outlier, an old pit and some rabbit-burrows show gravel containing shell fragments.

Half a mile south-south-east of Keelby a large Chalk-pit shows, near the middle of the north-east side,—

Stony soil	1	feet.
Loamy bedded Sand, with a few scattered stones	5	
Rolled Gravel of Boulder Clay stones	5	
Chalk with flints, dip to the north-east, very slight	20+	

At one spot in this pit, near the wood, about 2½ feet of Boulder Clay is preserved beneath the Gravel, which is here a well-worn very coarse shingle, principally of Chalk and flint.

In Riby Grove several sand-pits have been opened, but the only section now to be seen (1883) is just west of the house:—

Gravelly Sand, with shell fragments and a few perfect shells - - - - - - - 4 feet.

Unfortunately this is a very small and bad exposure, but it is evidently highly fossiliferous, and with a clean section more than the 18 species found ought to be obtained.

Irby Dale appears to have been another old fiord, the Gravel running up it in much the same way as at Croxton; but now the Marine Beds are only represented by patches separated by denudation. One of these caps an isolated Chalk hill rising in the middle of the Dale due north of Irby. Another, a little higher up, clings to the west side at Irby Dale woods. A pit in this outlier shows—

Fine false-bedded sand and gravel, with carbonaceous matter, and fragments of *Cardium edule*, *Tellina balthica* *Mactra subtruncata*, *Astarte borealis* and *Mya*, sp. - 4 feet.

Still higher up the valley a pit in the outlier above the Folly gives—

	Feet.
Rubbly and worn Chalk Gravel, with a few foreign pebbles	20+

This is capped at the lower end by a foot of chalky Boulder Clay; and from the clayey wet nature of the ground to the south there may be a small outlier of Boulder-Clay extending a few chains in that direction. The Gravel would seem to be a high-lying estuarine or fresh-water equivalent of the Marine Beds.

The isolated Chalk hill immediately north of Swallow village is also capped by similar gravel. In a pit close to the last house there is—

Gravel of rolled Chalk, with a few Boulder Clay stones	5	feet.
Chalk with flint nodules	10	

The higher parts of this large Dale apparently contain no Gravel.

North of Irby Holmes Wood there is an old pit in similar rolled Chalk Gravel, resting partly on Chalk. Its relation to the Boulder Clay is not clear, though it probably passes under the clay.

Returning to the open country, the only pit between Riby and Laceby is a large one in Laceby Hill. This hill rises as a conspicuous mound, like those north of the Humber, to a height of about 50 or 60 feet. The section is:—

False-bedded gravelly Sand, with masses of Shingle in the lower part (worked till water is reached) - - 40 feet.

Abundance of Boulder Clay stones are found, though Boulder Clay cannot here be seen either above or below the Gravel. Boulders of Chalk bored by *Pholas* and annelids are common. Fossils are plentiful and well-preserved, but the only important difference between the list and that from Kelsey Hill is the entire absence of the fresh-water *Corbicula fluminalis* from Laceby. No fresh-water shells and no mammalian bones have yet been found there.

South of Laceby the Gravels are abruptly overlapped by Boulder Clay, and for a long distance cannot be found. North-east of Laceby, after disappearing for about a mile, they re-appear in the shallow valley of Laceby Beck, and are probably close to the surface, though never rising to any height, all the way from Laceby to the Humber Marshes.

At Great Coates there is an interesting inlier, cut into by the Beck. A pit a short distance from the north-east side shows,—

	Feet.
Boulder Clay, purple and chalky (on the higher ground)	1 to 5
Gravelly Sand, with shell fragments principally near the top - - - - - - - -	12

This pit was deepened till water was reached, and shows that the base of the Sand must be below the level of the Marsh, which is about the level of ordinary high tides. Mr. Cordeaux and I obtained here 17 species of mollusca.* They are very fragmentary, though small light shells are sometimes little injured. Special attention was paid to this pit, as it is one of the few places where Boulder Clay can be clearly seen in section vertically over the shelly Gravels.

The same sand bed passes under the Boulder Clay on which Great Coates is built, and supplies the wells. Mr. Cordeaux also informs me that in lowering the cellar at his house this bed was cut into, and yielded such a constant supply of water that a special drain had to be constructed to carry it away. From the amount of water it would appear that sand must extend for some distance under the Boulder Clay; and it is probable that the bed is continuous with the outcrops in Laceby Beck, and bordering on the Marsh between Little Coates and Grimsby.

In Grimsby itself, close to the Roman Catholic church, a small sand-hill rose above the level of the Marsh, but has lately been almost entirely dug away. It showed sandy Gravel with rare shell fragments, including portion of *Venus gallina*, overlaid by a much-weathered mottled stony Boulder Clay, with little or no Chalk. In the recently completed drainage works, which lie considerably beneath high-water level, the upper Boulder Clay was seen gradually to cut through this Sand towards the Humber, and in places to rest directly on the lower Boulder Clay, with only a reddish line of division. The base of the Sand also sinks in the same direction, though more slowly. At the corner of Wellington Street and Heneage Street the section was:—

	Feet.
Soil and made ground - - - - - -	2
Peaty clay - - - - - - - -	5
Boulder Clay, chalky - - - - - -	3
Sand with stones and shell fragments (rising to the south) *Cardium edule*, *Tellina balthica*, *Mactra subtruncata*? *Mya*, sp. - - - - -	2½
Boulder Clay, chalky - - - - -	0½+
	13

* *See* table in Geology of Holderness, p. 70.

The surface of the ground is about the sea level.

Eastward this is the last section of the Marine Gravels, which apparently sink beneath the sea level, or are cut out by the newer Boulder Clay. Southward there are no more exposures in the district under consideration, but, as pointed out to me by Mr. Jukes-Browne, the bed re-appears 20 miles away, beyond Louth.

In the "Geology of Holderness" I have given an outline of the Physical Geography and Natural History of this period, and full lists of fossils. It is therefore unnecessary to treat of these again.

Post-glacial Deposits.

Owing to the difficulty often found in separating the Recent Deposits from those of older date, part of these have already been described in the last chapter. It now remains to describe the undoubtedly Post-glacial Peat, Alluvium, and Warp.

Large areas in the eastern part of Sheet 86 are occupied by Alluvial flats liable to be flooded by any unusually high tide or heavy rainfall. Much of this land—now some of the most valuable in the district—was permanently under water within the period of written history. A still larger area was formerly carr-land or tidal flat, though now protected by embankment and often raised by artificial warping. There are, however, a few sections in older beds of Post-glacial date which must be described before the Recent Alluvium. These are of very limited area, but of great interest, pointing as they do to a probable former submergence of about 40 feet.

Peat, Clay, and Brick-earth.

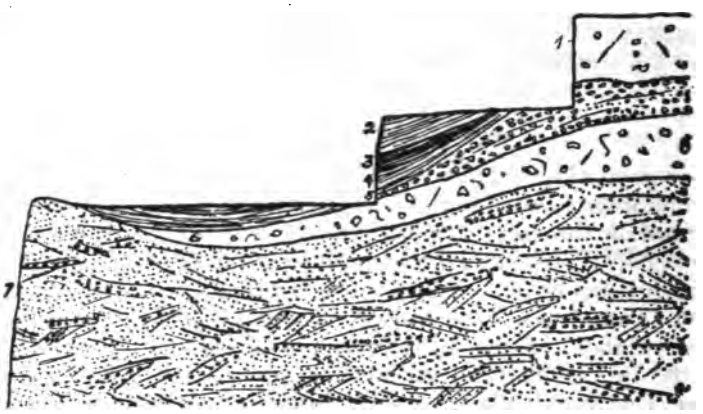
South of the Humber there is shingle near Barton, which, though coloured on the map as Glacial, has very much the look of a raised estuarine beach. The same beach can be followed, though perhaps not continuously, round the escarpment of the Chalk to beyond Horkstow. Not rising more than 50 feet above the sea, it forms for several miles a terrace at the foot of the Wolds.

Crossing the Humber there is one deposit, which from its peculiar position, can only be referred to a period of submergence. This is a peaty fresh-water bed, occurring in what at first seems a most unlikely place, —the top of an isolated sand-hill rising boldly 40 feet out of the marsh. The cross-section, shown in Fig. 10, is constructed from faces exposed in the new pit at Kelsey Hill during May 1884. At the time of my first visit the peaty clay had been cut back just beyond the deepest part of the hollow; on the second visit the faces were in the position noted. A few days later, and the evidence would probably be entirely destroyed, though fresh deposits might be cut into.

Over the Inter-glacial Sands and Gravels there is a very irregular capping of Boulder Clay, which has subsided into hollows, perhaps through the slipping of the sand when saturated with water. In one of these there is a fresh-water deposit, apparently formed in a pond about 50 feet wide in each direction. The peaty clay is full of plant remains and elytra of beetles, including a *Donacia*, which does not quite agree with any species known to Mr. C. O. Waterhouse, and a *Gyrinus* only determinable generically. It also yielded the much decayed wing-bone of a large bird. But all other calcareous fossils have disappeared, though the occasional

occurrence of the insoluble portion of the fruit of *Chara* shows that both it and shells may once have been abundant. The few plants determined throw no light on the climatic conditions. They were the pondweed, reed, and water-crowfoot, all species having a wide range. Overlying the clay

FIG. 10. *Cross-section of Gravel pit at Kelsey Hill.*



1 Stony brick-earth.
2 Blue clay,
3 Peaty bed, } Freshwater Beds.
4 Blue clay,
5 Earthy gravel.
6 Boulder Clay.
7 Marine gravel.

there is coarse unstratified gravel, which at one point appears to be banked against a vertical wall of Boulder Clay. When the gravel rests directly on the disturbed Marine Beds it is not easy to distinguish them; and this may account for the curious appearance of the southern end of the section, where the unstratified gravel looks almost as if it passed under Boulder Clay, though everywhere else it distinctly overlies it. Capping the hill and resting indiscriminately on any of the beds is a stony loam, with joints weathering green and mottled. At first this was taken to be a Boulder Clay, but closer examination showed that it was only a reconstructed bed, being full of small roots from top to bottom.

This Fresh-water Bed must have been formed when the submergence was about 40 feet, for it rests partly on porous gravel, and water could not remain in the pond unless the line of saturation were 40 feet higher than now. The coarse gravels also show the agency of running water; yet Kelsey Hill is now considerably the highest point in the neighbourhood, and the lower area with which it is connected is almost an island. On three sides it is surrounded by marshes at the sea level, and on the fourth by a low tract of land, not more than 10 feet above the sea, through which the Junction Drain has been carried. It seems, therefore, that not only has the sea-level altered, but many of the valleys in the Boulder Clay have been cut since the period of the Raised Beaches.

Alluvium and Warp.

Turning next to the estuarine Warp and the accompanying "Submerged Forests" of the Humber shore, we find that the only sections of the older portion have been seen during the excavation of the docks at Hull.*

* Grimsby Docks are in Sheet 85. They are described in the "Geology of Holderness."

Writing in 1866, Dr. Foster thus describes the beds exposed in the Albert Docks* :—

"In the cuttings at the east end, the upper stratum is silt, ... and immediately under the silt the trunks, roots, and branches of oak trees, together with a peat soil of two feet in thickness, beneath that a strong clay soil, and under this (so far as is uncovered) an extensive bed of blue sand, containing the fresh-water *Lymnæa, Planorbis, &c.*

"At a depth of 40 feet below the level of the adjoining land, trees (chiefly oak) are found in all positions; those which are upright and still *in situ* having been broken off within three feet of the roots. One oak-tree, of noble dimensions, is perfectly straight, its trunk being 45 feet long, and in the thickest part measuring 12½ feet in circumference; it is tolerably sound, but blackened in colour. This tree lies nearly north and south, but others, which have also fallen, are to be met with in every direction.

"In a hole caused by the decay of a branch, was found a quantity of hazel-nuts, possibly the winter store of some provident squirrel; the shells, though black, were quite perfect.

"The undulating state of the original surface may be seen by the silt above being of a lighter colour than the lower stratum. It is evident, from the position of the roots, that the ground on the north or land side, on which the trees grew, has been higher than the south or river side. . . . The trees . . . would require at least 300 years to attain the dimensions given."

According to Messrs. Wood and Rome† these docks—

"showed the Hessle Clay . . . . . irregularly denuded and overlain by a bed of silt upwards of 20 feet thick, at the bottom of which were the remains of a forest growing upon, and with the stools in places rooted into, the Hessle Clay. This deep accumulation of silt abounded to the very bottom (where the shells rested on the forest) with the ordinary estuarine mollusca of the Humber,—*Scrobicularia piperata, Tellina solidula, Cardium edule, Littorina littorea, &c.* In part this forest-bed was also underlain by the silt, showing an oscillation of level during its growth . . . . At Hull the dock-borings showed this forest to be now from 20 to 37 feet below high-water mark of ordinary spring tides."

After the completion of the works Mr. J. C. Hawkshaw read a paper, unfortunately only published in abstract, giving fuller particulars of the sections exposed.‡ From this abstract the following account of the peat bed is taken :—

"The Albert Dock extends for 4,000 feet along the Humber foreshore, and all the excavations were carried to a depth of at least 8 feet, and in some instances of 27 feet, below the level of low water.

"Before the commencement of the excavations the Hessle Clay, peat, and overlying silt were met with in succession on the foreshore, the level of the top of the peat bed at the west end of the area being about three feet above the level of low water, and its thickness from three to four feet. Eastward the bed followed the undulations of the clay without much variation in general level for half a mile, when it began to dip, attaining a depth of 12 feet below low-water level at the lock entrance, and then rising again. From this depression of the peat-bed, and the appearance

* "On the Discovery of Ancient Trees below the surface of the Land at the Western Dock now being constructed at Hull."—*Rep. Brit. Assoc.* for 1866 *Trans. of Sections*, p. 52.

† "On the Glacial and Post-glacial Structure of Lincolnshire and South-east Yorkshire."—*Quart. Journ. Geol. Soc.*, Vol. xxiv., p. 157; 1868.

‡ "Notes on the Peat and Underlying Beds observed in the construction of the Albert Dock, Hull."—*Quart. Journ. Geol. Soc.*, vol. xxvii., p. 237; 1871. See also *Proc. Inst. C.E.*, vol. xli., p. 92, Pl. viii. x; 1875.

of the overlying silts, the author thought it probable that this had been an old channel of the river Hull. . . . .

"The peat rested directly on the Hessle Clay, into which roots penetrated to a distance of five or six feet, generally following the direction of vertical joints. . . .

"At its highest level, at the west end of the dock, the peat consisted almost entirely of vegetable matters, including large accumulations of moss, leaves, and masses of brushwood, layers of oak-leaves with acorns, hazel-nuts, and fir-cones. Numerous remains of Coleoptera, chiefly wing-cases, were found. Trunks of oak trees, some of them 60 feet long, were scattered through the peat, and had evidently fallen where it grew; and, from the characters presented by most of them, it would appear that they had grown close together. In this part of the bed, at the level of low-water, and beneath a thick layer of moss, the remains of a fire were found. The author suggested that, from the small extent occupied by the remains of this fire, it was probably the result of human agency, as, if it had originated by lightning or by the friction of dry branches, it could hardly have been confined to so small an area.

"With regard to changes of level, whilst in other places an upward movement has been indicated, the area examined seems to furnish evidence only of depression. Thus the surface of the peat in the supposed old channel of the river Hull is 12 feet below the level of low water, whilst the bed of the present river at South Bridge is only 6 feet below that level. The depression of the forest converted the land on which it grew into a marsh, where soft vegetable matter accumulated rapidly and soon covered up the fallen trees, the soundness of the timber indicating no long exposure to the weather. As the land continued to subside, the marsh was invaded by the waters of a tidal estuary, in which the Mollusca lived whose shells occur in the grey clay overlying the peat. and even in the peat itself. Of these the following forms occur:—*Scrobicularia piperata, Cardium edule, Tellina solidula, Hydrobia,* sp., and *Bullina obtusa*—all, except the last, in great abundance."

Turning now to the new Alexandra Docks, which are about 2 miles lower down the Humber, we find very similar sections, showing an old land surface at the same level, or perhaps slightly lower. In May 1884 the following section was measured, but since the water was shut out and the Dock drained, the warp has subsided considerably.

The top of the section is now probably below the level of mean tide, though originally slightly higher. The lowest point reached at this spot is 52 feet below the coping:—

	Feet.
Clayey Warp - - - - - about	15
Warp sand, increasing towards the shore - -	5 to 0
Clayey Gravel with *Littorina* - - - -	1
Traces of the "Submerged Forest," consisting of a peaty seam with occasional tree-stumps. This bed is here much eroded by the overlying Gravel, but the underlying Boulder Clay is often full of small roots	
Reddish-purple chalky and stony Boulder Clay, much weathered in the upper part, but where the bed is thick the base is very like the older Boulder Clay. Blue joints occur throughout, though principally in the higher portion. Much Chalk and flint, Carboniferous Limestone, Coal Measure? Sandstone, Greenstone, Quartz, Porphyry, &c. &c. - - about	6
Fine bedded chalky Sand, without fossils - about	6
Dark purple, very chalky, Boulder Clay, unweathered -	4+
	32

Another part of the Docks gave:—

	Feet.
Warp (silty sand)	18
Lignite and peat	2
Gravel.	

Probably Boulder Clay would be found immediately beneath.

A year previously many tree-stumps had been seen on about the same level at another point; but so much water was coming in, that they could not be properly examined to ascertain whether they were actually rooted in the clay. The stumps subsequently seen were fewer in number, but had certainly grown where they are now found; most of them were small, but the navvies stated that now and then large trees occur. All the stumps observed appear to be oak.

The overlying warp contains abundance of shells, the common Humber species, *Scrobicularia plana*, *Tellina balthica* (thin-shelled and small), *Cardium edule* (stunted), *Hydrobia ulvæ*, and *Bulla obtusa* being scattered throughout, though other forms are rare. A boat was also found in the warp, and a bronze dagger. Warp, however, is so rapidly deposited that the depth at which such articles occur is no evidence of their antiquity. In the buried forest itself no trace of the contemporaneous existence of man appears to have been noticed in these excavations; and the remains of a fire, probably caused by human agency, is still the only fact pointing in that direction.

Similar sections were seen in Grimsby Docks (in Sheet 85). These are described in the "Geology of Holderness," in which will also be found an account of a large number of well-sections and trial borings on the marshes, and also a fuller account of the recent warp of the Humber in the area east of Hessle and Ferriby.

The small strips of Alluvium bordering the becks east of the Wolds call for no special remark, as no deep sections are visible. The surface is usually very peaty.

C. R.

APPENDIX.

APPENDIX I.

SYNOPTICAL TABLES OF FOSSILS OBTAINED WITHIN THE DISTRICT. COMPILED BY W. A. E. USSHER:—

(1.) LOWER LIAS.
(2.) MIDDLE LIAS.
(3.) INFERIOR OOLITE SERIES.
(4.) GREAT OOLITE SERIES.
(5.) MIDDLE AND UPPER OOLITES.

The Tables include Mr. Cross's lists; the fossils collected by the officers of the Survey have been identified by Messrs. Sharman and Newton.

Lists of fossils from the following rocks and deposits will be found in the text:—

Rhætic Beds, p. 9; Cretaceous, pp. 108, 109, 119; Drift, pp. 160, 175–187.

(1.) LOWER LIAS FOSSILS.

FOSSILS.	Limestone and Clay below Frodingham Ironstone.			Frodingham Ironstone.			Clay above Frodingham Ironstone.		
	Basement Beds.	Cross, Lowest Lias.	Cross, Frodingham Cutting.	Coleby and Frodingham Quarries.	Quarries, Pits, &c. South of Frodingham Quarries.	Cross's List.	Sheffield Hill.	South of the Frodingham Quarries.	Cross's List.
PLANTÆ.									
Wood (found by Messrs. Daglish and Howse)	•	•	•	×					
CŒLENTERATA.									
Montlivaltia Haimei, *Chap.*	•	×	×						
ECHINODERMATA.									
Crinoid arms	•	•	•	×					
Extracrinus	•	•	•	×					
Pentacrinus	•	×	2 sp.	•	•	•	•	•	Very rare ×
Plumaster ophiuroides, *Wright*	•	•	•	×					
Spines of Cidaris	•	×							

FOSSILS.	Limestone and Clay below Frodingham Ironstone.			Frodingham Ironstone.			Clay above Frodingham Ironstone.		
	Basement Beds.	Cross, Lowest Lias.	Cross, Frodingham Cutting.	Coleby and Frodingham Quarries.	Quarries, Pits, &c. South of Frodingham Quarries.	Cross's List.	Sheffield Hill.	South of the Frodingham Quarries.	Cross's List.
ANNELIDA.									
Serpula	.	.	.	×	.	.	.	×	
BRACHIOPODA.									
Rhynchonella	.	.	×	.	.	.	.	×	
„ tetrahedra, *Sow.*	.	.	.	.	.	.	×		
Spiriferina	.	.	.	.	.	.	.	.	Very rare
„ Walcotti, *Sow.*	.	.	×	.	.	×	.	×	×
Terebratula numismalis, *Lam.*	.	.	.	.	.	.	.	.	×
„ numismalis, var. ovalis, *Quenst.*	.	.	.	.	.	.	.	.	×
„ punctata, *Sow.*	.	.	.	.	.	.	×	×	
LAMELLIBRANCHIATA.									
Arca	×								
Astarte	×								
„ dentilabrum, *Eth.*	.	.	.	.	.	×			
„ obliqua, *Desh.*	.	×							
Avicula decussata, *Goldf.*	.	×							
„ inæquivalvis, *Sow.*	.	.	×	.	.	.	.	×	
Cardinia concinna, *Sow.*	.	.	×						
„ copides ? *Eyckh.*	.	.	.	.	.	×			
„ crassissima, *Ag.*	.	×	.	.	.	?			
„ gigantea, *Quenst.*	.	.	.	.	.	×			
„ Listeri, *Sow.*	.	×	×	.	×				
„ Listeri, var. ovalis, *Stutch.*	.	.	.	×					
„ Morrisi ? *Terq.*	.	.	.	.	.	×			
„ n. sp.	.	.	.	.	.	×			
„ (oval, sp.)	.	×							
Cardita Heberti ? *Terq.*	.	×							
Cardium	.	.	.	.	.	.	.	×	
Carpenteria (Terquemia)	.	×	.	.	.	×			
Crenatula ventricosa *Sow.*	.	.	.	.		.	×		

FOSSILS.	Limestone and Clay below Frodingham Ironstone.			Frodingham Ironstone.			Clay above Frodingham Ironstone.		
	Basement Beds.	Cross, Lowest Lias.	Cross, Frodingham Cutting.	Coleby and Frodingham Quarries.	Quarries, Pits, &c. South of Frodingham Quarries.	Cross's List.	Sheffield Hill.	South of the Frodingham Quarries.	Cross's List
LAMELLIBRANCHIATA—*cont.*									
Cucullæa	.	.	.	.	×				
„ ovum, *Quenst.*	.	.	.	.	.	×			
Gervillia betacalcis, *Quenst.*	.	.	.	.	.	×			
Gryphæa, n. sp.	.	×							
„ sp.	.	.	×	.	.	.	×	×	
„ arcuata, *Lam.* (= G. incurva, *Sow.*)	.	Rare ×	×	×	.	×			
„ Maccullochii, *Sow.*	.	.	.	.	×	.	.	.	×
Hinnites	×								
Hippopodium	.	.	.	.	.	.	×	×	
„ ponderosum, *Sow.*	.	.	.	.	.	.	×	×	
„ ferri-Eth.	.	.	.	.	.	×			
Homomya	.	×							
Lima antiquata, *Sow.*	.	.	.	.	.	.	?	×	
„ dupla, *Quenst.*	.	.	×	.	.	×			
„ gigantea, *Sow.*	×	×	×	.	×	×			
„ Hermanni, *Volts.*	.	×	×	.	.	×			
„ hettangiensis, *Terq.*	.	×	.	.	.	×			
„ pectinoides, *Sow.*	.	.	.	×	.	.	.	×	
„ (small ribbed sp.)	.	×							
„ (small single ribbed sp.)	.	.	×						
„ (small variety)	.	.	.	.	.	×			
Modiola	.	×	×						
„ minima, *Sow.*	×								
„ Morrisii, *Oppel.*	.	.	.	.	.	×			
„ nitidula, *Dunk.*	.	×							
„ oxynoti, *Quenst.*	.	.	.	.	.	×			
„ pygmæa, *Simps.*	×								
„ scalprum, *Sow.*	.	.	.	×	.	.	×	×	
Myacites (Pleuromya) liasinus, *Ziet.*	.	×							
„ „ unioides, *Röm.*	.	.	.	.	.	.	.	.	×
Myoconcha oxynoti, *Quenst.*	.	.	.	.	.	×			
Ostrea	×	.	.	.	.	.	.	×	

FOSSILS.	Limestone and Clay below Frodingham Ironstone.			Frodingham Ironstone.			Clay above Frodingham Ironstone.		
	Basement Beds.	Cross, Lowest Lias.	Cross, Frodingham Cutting.	Coleby and Frodingham Quarries.	Quarries, Pits, &c. South of Frodingham Quarries.	Cross's List.	Sheffield Hill.	South of the Frodingham Quarries.	Cross's List.
LAMELLIBRANCHIATA—*cont.*									
Ostrea arietis, *Quenst.*	.	.	×						
„ irregularis, *Goldf.*	.	×		-					
„ liassica, *Strickl.*	×	×		.					
„ rugata, *Quenst.*	.	×		.	.				
Pecten	.	.	.	.	×	.	×		
„ æqualis, *Quenst.*	.	.	.	.	.	×			
„ æquivalvis, *Sow.*	.	.	.	×	?	.	.	×	
„ demissus, *Phil.* (P. demissaries, *Cross*)	.	.	.	.	.	×			
„ lissinus, *Nyst.*	.	.	.	×	.	.	.	×	
„ (small ribbed sp.)	.	.	×						
„ (small smooth sp.)	.	×	×						
„ subulatus ?	.	.	.	.	.	.	.	×	
„ textorius, *Schl.*	.	.	×	×					
„ texturatus, *Goldf.*	.	.	.	.	.	×			
„ valoniensis? *Def.*	.	×							
Pholadomya	.	.	.	×					
„ ambigua, *Sow.*	.	.	×	.	.	×	×		
„ „ (very large)	.	.	.	.	.	.	.	.	×
„ „ (long var.)	.	.	.	.	×				
„ prima, *Quenst.*	.	×		-					
Pinna	.	.	×	.	.	.	×	×	
„ folium, *Y. & B.*	.	.	.	.	.	.	.	.	×
Pleuromya	×	.	.	.	.	.	×	×	
„ æquistriata, ? *Ag.*	.	.	.	.	.	.	.	×	
„ crowcombeia, *Moore*	×			-					
„ Dunkeri, *Röm.*	.	×		-					
Plicatula spinosa, *Sow.*	.	.	.	×	.	.	×	×	small +
Sanguinolaria striata, *Buckm.*	.	.	.	.	.	.	.	×	×
Tancredia ferrea, *Eth.*	.	.	.	.	.	×			
Unicardium cardioides *Phil.*	.	×	×	×	×	.	×		

FOSSILS.	Limestone and Clay below Frodingham Ironstone.			Frodingham Ironstone.			Clay above Frodingham Ironstone.		
	Basement Beds.	Cross, Lowest Lias.	Cross, Frodingham Cutting.	Coleby and Frodingham Quarries.	Quarries, Pits, &c. South of Frodingham Quarries.	Cross's List.	Sheffield Hill.	South of the Frodingham Quarries.	Cross's List.
GASTEROPODA.									
Cerithium, semele? *D'Orb.*	×								
Eucyclus Chapuisii, *T. & P.*	×								
Pleurotomaria	.	×	×	.	.	×			
„ anglica, *Sow.*	.	×							
„ basilica? *Chap.*	.	×							
„ psilonoti, *Quenst.*	.	×							
Frochus	.	.	×						
Turritella, Deshayesia? *Terq.*	.	×							
CEPHALOPODA.									
Ammonites angulatus, var. catenatus, *D'Orb.*	.	×							
„ „ var. moreanus, *D'Orb.*	.	×							
„ armatus, *Sow.*	.	.	.	.	.	.	.	×	
„ aureus, *Dum.*	.	.	.	.	.	×			
„ Bucklandi, *Sow.*	.	.	×	.	.	?			
„ Brookii, *Quenst.* (non *Sow.*)	.	.	.	.	.	×			
„ boucaultianus, *D'Orb.*	.	.	.	.	.	×			
„ capricornus, *Schl.*	.	.	.	.	.	.	.	×	
„ compressarius? *Quenst.*	.	.	.	.	.	×			
„ Conybeari, *Sow.*	.	.	×	.	.	×			
„ gmundensis, *Dum.*	.	.	.	.	.	×			
„ Henleyi, *Sow.*	.	.	.	.	.	.	.	.	×
„ Johnstoni, *Sow.*	.	×							
„ atæcosta, *Sow.*	.	.	.	.	.	.	.	×	
„ lineatus? *Schl.*	.	.	.	.	.	.	.	.	×
„ Loscombi, *Sow.*	.	.	.	.	.	.	.	.	×
„ natrix, var. rotundus, *Quenst.*	.	.	.	.	.	.	.	.	×
„ oxynotus, var. numismalis, *Quenst.*	.	.	.	.	.	.	.	.	×
„ polymorphus, var. mixtus? *Quenst.*	.	.	.	.	.	.	.	.	×

FOSSILS.	Limestone and Clay below Frodingham Ironstone.			Frodingham Ironstone.			Clay above Frodingham Ironstone.		
	Basement Beds.	Cross, Lowest Lias.	Cross, Frodingham Cutting.	Coleby and Frodingham Quarries.	Quarries, Pits, &c. South of Frodingham Quarries.	Cross's List.	Sheffield Hill.	South of the Frodingham Quarries.	Cross's List.
CEPHALOPODA—*cont.*									
Ammonites raricostatus, *Ziet.*	•	•	•	•	•	•	•	•	×
„ scipionianus ? *Quenst.*	•	•	•	•	•	×			
„ semicostatus, *Y. & B.*	•	•	×	×	×	×			
„ Taylori, *Sow.*	•	•	•	•	•	•	•	•	×
„ (young)	×	•	•	•	•	•	×	×	
Belemnites	•	•	•	×	×				
„ acutus, *Mill.*	•	•	×	•	•	×			
„ clavatus, *Schl.*	•	•	•	•	•	•	•	•	×
„ paxillosus, *Schl.*	•	•	•	•	•	•	•	•	×
Nautilus striatus, *Sow.*	•	×	×	•	•	×			
PISCES.									
Hybodus	•	•	•	•	×				
REPTILIA.									
Ichthyosaurus communis, *Conybeare* (mentioned by Daglish and Howse).	•	•	•	×					

(2.) Middle Lias Fossils.

FOSSILS.	Pecten Bed.						Middle Lias Clay.			Rock Bed.			
	Mr. Cross's List.	Ditch ¼ mile West of Roxby.	Pit on slope of Sheffield Hill.	¼ mile N.N.W. of Manby.	20 chains S.S.W. of Twigmoor.	2 miles from Messingham Church.	Santon Railway Cutting, Mr. Cross's List ×; subsequently found +.	North of Cleatham and South of Santon Cutting.	¼ mile South of Cleatham.	Santon Railway Cutting, Mr. Cross's List.	Near road to West Halton ✠; 1 mile West of Appleby Station near Daw's Pit ×.	¼ mile North of Manby House ✠; 15 chains South of Manton Warren House ×.	¼ mile South of Cleatham.
PLANTÆ.													
Wood									×				
Ditrupa etalense, *Piette*												×	
BRACHIOPODA.													
Rhynchonella											×		
„ tetrahedra, *Sow.*		×			×	×				×	×	×	×
„ variabilis, *Schl.*	×						×						
Terebratula								×					
„ Edwardsi, *Dav.*													×
„ punctata, *Sow.*	×										×	✠	×
„ subpunctata, *Dav.*										×			
Spiriferina	Very rare.									Very rare.			
LAMELLIBRANCHIATA.													
Avicula cygnipes, *Phil.* (Y. & B.)										×			
„ inæquivalvis, *Sow.*							×	×	×			×	×
Cardinia hybrida, *Sow.*	×												
„ Listeri, *Stutch*		×	×										
Cardita		×				?							
Cardium lobatum ? *Quenst.*							×						
„ multicostatum, *Phil.*	×												
Cucullæa	×												
Cypricardia	×				×	×							
„ intermedia, *Moore*		×	×			×							

FOSSILS.	Pecten Bed.						Middle Lias Clay.		Rock Bed.			
	Mr. Cross's List.	Ditch ¼ mile west of Roxby.	Pit on slope of Sheffield Hill.	½ mile N.N.W. of Manby.	20 chains S.S.W. of Twigmoor.	2 miles from Messingham Church.	Santon Railway Cutting. Mr. Cross's List ×; subsequently found +.	North of Cleatham and South of Santon Cutting.	½ mile S. of Cleatham.	Santon Railway Cutting, Mr. Cross's List.	Near road to West Halton ✠; 1 mile West of Appleby Station near Daw's Pit ×.	½ mile North of Manby House ✠; 15 chains South of Manton Warren House ×.	½ mile South of Cleatham.
LAMELLIBRANCHIATA— *cont.*													
Cyprina	×												
Gervillia lævis ? *Buckm.*	.	.	.	.	.	.	×						
Goniomya	rare	.	.	.	.	.	rare			×			
Gresslya lunulata, *Tate* (like Myacites).	.	.	.	.	×								
Gryphæa cymbium, *Lam.*	.	.	.	.	×								
„ gigantea, *Sow.*	.	×											
Hippopodium ponderosum, *Sow.*	.	.	.	.	.	.	.	×					
Isocardia (like minima, *Goldf.*)	.	.	.	.	.	.	.	.	.	.	.	✠	
Lima	.	×											
„ acuticosta, *Quenst.*	.	.	.	.	.	.	×						
„ antiquata, *Sow.*	×	?											
„ Hermanni, *Voltz*	×												
„ (like gigantea, *Sow.*)	.	.	.	.	.	.			×				
„ pectinoides, *Sow.*	.	.	.	.	.	.		×					
Modiola scalprum, *Sow.*	.	.	.	×	×								
Myacites (Pleuromya)	.	.	.	.	.	.	2 sp.	.	.	.	×		
„ „ unioides, *Röm.*	×	.	.	×	×	×	.	.	.	×		×	
Nucula	×												
„ (? Leda) complanata, *Phil.*	.	.	.	.	.	.	×						
„ inflata, *Quenst.*	.	.	.	.	.	.	×						
Ostrea irregularis, *Münst.*	.	.	.	.	.	.	.	.	×				
„ læviuscula, *Sow.*	.	.	.	.	.	.	×						
Pecten	.	.	.	.	.	.	.	×	×	.	.	.	×
„ æqualis, *Quenst.*	.	.	.	×			+						
„ æquivalvis, *Sow.*	.	×	×	.	×	.	.	.	.	.	.	×	×
„ corneus, *Goldf.*	×												
„ liasinus, *Nyst.*	.	.	×										
„ textorius, *Schl.*	.	.	.	.	.	.	.	.	.	.	.	.	×

FOSSILS.	Pecten Bed.						Middle Lias Clay.			Rock Bed.			
	Mr. Cross's List.	Ditch ¾ mile West of Rorby.	Pit on slope of Sheffield Hill.	¾ mile N.N.W. of Manby.	20 chains S.S.W. of Twigmoor.	2 miles from Messingham Church.	Santon Railway Cutting, Mr. Cross's List ×; subsequently found +.	North of Cleatham and South of Santon Cutting.	¾ mile South of Cleatham.	Santon Railway Cutting, Mr. Cross's List.	Near road to West Halton ¾; 1 mile West of Appleby Station, near Daw's Pit ×.	¾ mile North of Manby House ¾; 15 chains South of Manton Warren House ×.	¾ mile South of Cleatham.
LAMELLIBRANCHIATA—*cont.*													
Pecten (like sublævis, *Phil.*)	×												
Pholadomya ambigua, *Sow.*	.	.	.	.	.	.	+						
Pinna	.	.	.	.	×	.	×						
Plicatula spinosa, *Sow.*	.	.	.	.	.	.	×						
Tancredia liassica, *Eth.*	×												
„ ovata, *Terq. & Piette*	.	×	×	.	.	.	small						
Unicardium cardioides, *Phil.*	×												
„ globosum, *Moore*	.	.	.	.	.	×							
GASTEROPODA.													
Cryptænia	.	.	.	.	.	.	.	×					
Natica	.	.	.	.	×	.	×						
Pleurotomaria	.	.	.	×	×	×							
Turbo	.	.	.	.	.	.	.	.	×				
CEPHALOPODA.													
Ammonites	.	.	.	.	.	.	.	×					
„ armatus, *Sow.*	×												
„ capricornus, *Schl.* (= A. maculatus, *Y. & B.*)	.	.	.	.	.	.	× +	.	×				
„ communis, *Sow.*	.	.	.	.	.	.	.	.	.	×			
„ cornucopia, *Y. & B.*	.	.	.	.	.	.	.	.	.	×			
„ Henleyi, *Sow.*	×												
„ striatus, *Rein.*	.	.	.	×									
„ serpentinus, *Rein.*	.	.	.	.	.	.	.	.	.	×			
„ spinatus, *Brug.*	.	.	.	.	.	.	.	.	.	×			

FOSSILS.	Pecten Bed.						Middle Lias Clay.			Rock Bed.			
	Mr. Cross's List.	Ditch ¼ mile West of Roxby.	Pit on slope of Sheffield Hill.	½ mile N.N.W. of Manby.	20 chains S.S.W. of Twigmoor.	2 miles from Messingham Church.	Santon Railway Cutting, Mr. Cross's List ×; subsequently found +.	North of Cleatham and South of Santon Cutting.	½ mile South of Cleatham.	Santon Railway Cutting, Mr. Cross's List.	Near road to West Halton ✠; 1 mile West of Appleby Station, near Daw's Pit ×.	½ mile North of Manby House ✠; 15 chains South of Manton Warren House ×.	½ mile South of Cleatham.
CEPHALOPODA—*cont.*													
Belemnites - - -	.	.	×	.	.	.	+	.	.	.	✠	×	×
„ acutus, *Miller* -	.	.	.	.	.	.	.	.	.	.	.	.	×
„ acuarius, *Schl.* -	.	.	.	.	.	.	.	.	×	.	.	.	×
„ breviformis, *Volts* -	.	.	.	.	.	.	.	.	.	.	×	.	×
„ clavatus, *Schl.* -	.	.	.	.	.	.	.	.	.	.	✠		
„ elongatus, *Miller* -	×									large			
„ paxillosus, *Schl.* -	.	.	.	.	.	.	×	.	.	×			

The Upper Lias fossils collected in Sheet 86 were obtained from the Kirton Station Railway Cutting, vide p. 56. Including *Am. serpentinus*, discovered near Roxby, of 10 species found, five occur in the Middle Lias, viz.:—

Terebratula punctata, *Sow.*
Lima pectinoides, *Sow.*
Myacites (Pleuromya) unioides, *Röm.*
Ammonites communis, *Sow.*
A. serpentinus, *Rein.*

The three forms first mentioned are also found in the Lower Lias.

(3.) Inferior Oolite Fossils.

FOSSILS.	Basement Beds.	Mr. Cross's List.			Kirton Beds.	Hibaldstow Beds.
		Santon Beds.	Above Santon Beds (? Kirton).	Upper Beds (? Hibaldstow).		
PLANTÆ.						
Fucoid	.	.	.	.	×	
Wood	.	.	.	.	×	
CŒLENTERATA.						
Small Corals	.	.	×			
Obscure Corals	.	.	.	×		
Isastræa Conybeari, *M. Edw.*	.	.	.	.	×	
„ Richardsoni, *Ed. & H.*	.	.	.	.	×	
Latimæandra Flemingii, *Ed. & H.*	.	.	.	.	×	
Montlivaltia	.	.	.	.	×	
Thamnastræa Defranciana, *Mich.*	.	.	.	.	×	
Thecosmilia gregaria, *M'Coy*	.	.	.	.	×	
ECHINODERMATA.						
Acrosalenia	.	.	.	.	.	×
Cidaris	.	.	×	×		
Echinus	.	.	×	×		
Galeropygus agariciformis, *Forbes*	×					
Pentacrinus (dwarf sp.)	.	.	×			
Pseudodiadema depressa, *Ag.*	.	.	.	.	×	
ANNELIDA.						
Serpula	.	.	×	×		
„ socialis, *Goldf.*	.	.	.	.	×	
CRUSTACEA.						
Crustacean claw	.	.	.	.	×	
Glyphæa	.	×				
BRACHIOPODA.						
Rhynchonella	.	.	.	.	×	
„ spinosa *Schl.*, var. Crossii, *Walker*	.	.	.	×	?	
„ spinosa, *Schl.*	.	.	.	.	.	?
„ quadriduplicata, *Dav.*	.	.	.	?		

FOSSILS.	Basement Beds.	Mr. Cross's List.			Kirton Beds.	Hibaldstow Beds.
		Santon Beds.	Above Santon Beds (? Kirton).	Upper Beds (? Hibaldstow).		
BRACHIOPODA—*cont.*						
Rhynchonella subangulata, *Dav.*	.	.	.	.	?	
Terebratula	.	.	.	.	×	
„ globata, *Sow.*	.	.	.	.	×	
„ maxillata, *Sow.*	.	.	.	.	×	
„ submaxillata, *Mor.*	.	.	.	×		
Waldheimia ornithocephala, *Sow.*	.	.	.	×		
LAMELLIBRANCHIATA.						
Arca pulchra, *Sow.*	.	.	.	?		
Astarte	.	.	.	.	.	×
„ divaricata, *Eth.*	.	.	×			
„ elegans, *Sow.*	.	.	×			
„ interlineata, *Lyc.*	.	.	.	.	×	
„ minima, *Sow.*	.	.	×			
„ pumila, *Sow.*	.	.	×			
„ recondita, *Phil.*	.	.	×			
„ rhomboidalis, *Phil.*	.	.	.	×		
„ squamula, *D'Arch.*	.	.	×			
Avicula	.	.	.	.	×	
Cardium	×	.	.	×		
„ striatulum, *Phil.* [Buckmani, *Lyc. & Mor.*]	.	.	×			
„ (like cognatum, *Phil.*)	.	.	×			
Ceromya bajociana, *D'Orb.*	.	×	×			
„ cornuta, *Cross.* MS. n. sp.	.	×				
Corbicella complanata, *Lyc.*	.	.	×			
Corbis Lajoyei, *D'Arch.*, var. cingenda, *Lyc.*	.	.	.	.	×	
„ rotunda, *Lyc. & Mor.*	×					
Corbula	.	.	×	.	?	
Cucullæa oblonga, *Sow.*	.	.	×			
„ ornata, *Phil.*	.	.	×			
„ Rolandi, *Eth.*	.	.	×			
Cypricardia	×	.	.	.	×	
„ acutangula, *Phil.*	.	.	.	×		
„ bathonica, *D'Orb.*	.	.	×			
Cyprina trapesiformis, *Röm.*	.	.	×			
Gervillia acuta, *Sow.*	.	×	×	×	×	

FOSSILS.	Basement Beds.	Mr. Cross's List.			Kirton Beds.	Hibaldstow Beds.
		Scarton Beds.	Above Scarton Beds (? Kirton).	Upper Beds (? Hibaldstow).		
LAMELLIBRANCHIATA—*cont.*						
Gervillia (or Pteroperna)	.	.	.	.	×	
Goniomya V-scripta, *Sow.*	.	.	.	×		
Gresslya	.	.	?			
„ abducta, *Phil.*	.	.	.	.	×	
Hinnites abjectus, *Phil.*	.	×	×	×		
Homomya crassiuscula, *Lyc. & Mor.*	.	.	.	×		
„ gibbosa, *Sow.*	.	.	.	×	×	
Isocardia	×	.	.	.	.	×
cordata, *Buckm.*	.	.	×			
Lima	.	.	.	.	×	×
„ bellula, *Lyc.*	.	.	.	×	×	
„ duplicata, *Sow.*	.	.	.	×	×	
„ (large sp., like Hermanni)	.	.	×			
„ lævis, *Cross.* MS. n. sp ?	.	.	.	×		
„ pectiniformis, *Schloth.* (L. proboscidea, *Sow.*)	.	.	.	×	×	
„ punctata, *Sow.*	.	.	.	.	×	
„ rigidula, *Phil.*	.	.	×			
„ sulcata, *Cross.* MS. n. sp ?	.	.	.	×		
Lithodomus	.	.	.	×		
„ (small ornamented sp.)	.	.	.	.	×	
„ (small smooth sp.)	.	.	.	.	×	
Lucina Bellona, *D'Orb.*	.	.	.	×	×	×
burtonensis, *Lyc.*	.	.	.	.	×	
Macrodon hirsonensis, *Lyc. & Mor.*	.	.	×			
Modiola aspera, *Sow.*	.	.	.	×		
„ cuneata, *Sow.*	.	.	?			
„ Leckenbyi, *Lyc. & Mor.*	.	.	×	×		
„ Lonsdalei, *Lyc.*	.	.	.	×		
„ sowerbyana, *D'Orb.*	×					
„ ungulata, *Y. & B.*	.	×	.	×		
Myacites	.	.	×	.	×	
„ jurassi, *Brong.*	.	.	.	.	×	
„ (Homomya) Vezelayi, *D'Arch.*	.	.	.	.	×	
Myopsis	×					
Nucula Hammeri, *Def.*	.	.	×			

FOSSILS.	Basement Beds.	Mr. Cross's List.			Kirton Beds.	Hildaldstow Beds.
		Scarton Beds.	Above Scarton Beds (? Kirton).	Upper Beds (? Hildaldstow).		
LAMELLIBRANCHIATA—*cont.*						
Nucula variabilis, *Sow.*	.	.	×			
Opis cordiformis, *Lyc.*	.	.	×			
Ostrea gregaria, *Sow.*	.	.	.	×	×	
„ (Gryphæa) mima, *Phil.*	.	×				
Pecten annulatus, *Sow.*	.	.	.	.	×	
„ aratus, *Waagen*	.	.	×	×	×	
„ articulatus, *Schl.*	.	.	.	×	×	
„ lens, *Sow.*	.	×	×	×	×	
Perna quadrata, *Phil.*	.	.	.	×		
Pholadomya fidicula, *Sow.*	.	×	×	×		
„ Heraulti, *Ag.*	×	.	×	×	×	
Pinna	.	.	.	.	×	
„ cuneata, *Sow.* or *Phil.*	.	×	.	×		
„ lanceolata, *Sow.*	.	.	.	.	×	
Pteroperna	.	.	.	×		
Quenstedtia oblita, *Phil.*	.	.	.	.	×	
Thracia	×					
Trichites nodosus, *Lyc.*	.	×				
Trigonia hemisphærica, *Lyc.*	.	.	×	×	×	
„ hemisphærica, var. gregaria, *Lyc.*	.	.	.	.	.	×
„ Phillipsii, *Lyc.*	.	.	×			
Unicardium	.	.	.	×		
GASTEROPODA.						
Alaria	.	.	×			
Amberleya	.	.	.	.	×	
Cerithium	.	.	×	×		
Cylindrites	.	.	.	.	×	
Dentalium	.	.	.	×		
Eulima	.	.	.	×		
Natica (Euspira)	.	.	×	×		
„ large sp. (cast)	.	.	.	×		
„ adducta, *Phil.*	.	.	.	×		
„ canaliculata, *Lyc. & Mor.*	.	.	.	.	×	
„ leckhamptonensis, *Lyc.*	.	.	.	×		

FOSSILS.	Basement Beds.	Mr. Cross's List.			Kirton Beds.	Hilbaldstow Beds.
		Santon Beds.	Above Santon Beds (? Kirton).	Upper Beds (? Hilbaldstow).		
GASTEROPODA—*cont.*						
Nerinæa	.	.	.	.	.	×
„ Jonesii, *Buckm.*	.	.	.	×		
„ Voltzii, *Desl.*	.	.	.	.	×	
„ (allied to N. cotteswoldiæ, *Lyc.*)	.	.	.	.	.	×
Neritopsis, n. sp.	.	.	.	×		
Patella rugosa, *Sow.*	.	.	.	×		
Pleurotomaria armata, *Münst.*	.	.	.	×		
„ pallium, *D'Orb.*	.	.	.	×		
Purpurina	.	.	.	×		
Trochus, n. sp.	.	.	×			
Turbo, n. sp.	.	.	×			
„ gemmatus, *Lyc.*	.	.	.	.	×	
„ oppeliensis, *Lyc.* (sinistral sp.)	.	.	.	×		
CEPHALOPODA.						
Ammonites, (large specimen Humphriesianus type)	.	.	.	×		
„ (allied to A. Truellii, *D'Orb.*)	.	×				
Belemnites	.	×	.	.	×	

(4.) Great Oolite Fossils.

FOSSILS.	Great Oolite Series.					
	Upper Estuarine Series.	Great Oolite Limestone	Great Oolite Clay.		Cornbrash.	
			Survey Collection List.	Mr. Cross's List.	Survey Collection List.	Mr. Cross's List.
ECHINODERMATA.						
Acrosalenia					×	
Clypeus Plottii, *Klein*					×	
Echinus						×
Holectypus depressus *Leske*					×	
ANNELIDA.						
Serpula		×				×
BRACHIOPODA.						
Rhynchonella						×
„ concinna, *Sow.*	×	×	×			dwarf ×
„ obsoleta, *Sow.*					×	
Terebratula		×				
„ intermedia, *Sow.*		×			×	
Waldheimia lagenalis, *Schl.*						×
„ oboyata, *Sow.*					×	×
„ ornithocephala, *Sow.*					×	
LAMELLIBRANCHIATA.						
Arca						rare ×
Astarte					×	
„ elegans, *Sow.*					×	
„ minima, *Sow.*						×
Avicula braamburiensis, *Phil.*					×	
„ echinata, *Sow.*		×			×	×
Cardium cognatum ?, *Phil.*						×
„ semicostatum, *Phil.*						×
„ Stricklandi, *Lyc. & Mor.*						×
Ceromya concentrica, *Sow.*					×	

FOSSILS.	Great Oolite Series.					
	Upper Estuarine Series.	Great Oolite Limestone.	Great Oolite Clay.		Cornbrash.	
			Survey Collection List.	Mr. Cross's List.	Survey Collection List.	Mr. Cross's List.
LAMELLIBRANCHIATA—*cont.*						
Corbicella	•	×				
„ bathonica ?, *Lyc. & Mor.*	•	•	•	•	•	×
Corbis (? rotunda, *Walton*)	•	•	•	•	•	×
Cypricardia	•	?	•	•	•	×
Gervillia crassicosta, *Lyc. & Mor.*	•	•	•	×		
„ ovata, *Sow.*	•	•	•	•	•	×
Goniomya V-scripta, *Sow.*	•	•	•	•	•	×
Gresslya	•	•	•	•	•	×
Isocardia nitida, *Phil.*	•	•	•	•	•	×
„ rostrata ?, *Sow.*	•	•	•	•	×	
Lima duplicata, *Sow.*	•	•	•	•	•	×
„ rigida, *Sow.*	•	×				
„ rigidula, *Phil.*	•	•	•	•	•	×
Lucina	•	×				
„ burtonensis ?, *Lyc.*	•	•	•	•	•	×
„ Lycetti, *Oppel* (= L. crassa, *Sow.*)	•	•	•	•	•	×
Modiola gibbosa ?, *Sow.*	•	•	•	•	×	×
„ imbricata, *Sow.*	×	×	•	•	×	×
„ Lonsdalei, *Lyc. & Mor.*	•	•	•	•	•	×
„ sowerbyana, *D'Orb.* (= M. plicata, *Sow.*)	•	•	•	•	•	×
„ ungulata, *Y. & B.*	•	•	•	×		
Myacites calceiformis, *Phil.*	•	×	•	•	×	×
„ decurtata, *Phil.*	•	•	•	•	×	var. ×
„ modica, *Bean.*	•	•	•	•	•	×
„ sinistra, *Ag.*	•	•	•	•	•	×
„ Vezelayi, *D'Arch.*	•	•	•	•	×	
Mytilus furcatus, *Goldf.*	•	×				
Nucula variabilis, *Sow.*	•	•	•	•	•	×
Opis, n. sp.	•	•	•	•	•	×
Ostrea gregaria, *Sow.*	•	•	×			
„ Sowerbyi, *Lyc. & Mor.*	×	× var.	×	×	×	
„ subrugulosa, *Lyc. & Mor.*	•	•	•	×		

FOSSILS.	Great Oolite Series.					
	Upper Estuarine Series.	Great Oolite Limestone.	Great Oolite Clay.		Cornbrash.	
			Survey Collection List.	Mr. Cross's List.	Survey Collection List.	Mr. Cross' List.
LAMELLIBRANCHIATA—*cont.*						
Pecten articulatus, *Schl.*	•	•	•	•	•	×
„ hemicostatus, *Phil.*	•	•	•	•	•	×
„ inæquicostatus, *Phil.*	•	•	•	•	•	×
„ lens, *Sow.*	•	•	•	•	•	×
„ rigidus, *Sow.*	•	•	•	•	•	×
„ subfibrosus, *D'Orb.*	•	•	•	•	•	×
„ vagans, *Sow.*	•	×				
Perna obliqua, *Walton*	•	•	•	•	•	×
„ quadrata, *Phil.*	•	•	•	×		
Pholadomya acuticosta, *Sow.*	•	•	•	•	•	×
„ Murchisonæ, *Sow.*	•	•	•	•	•	×
„ Phillipsi, *Mor.*	•	•	•	•	×	
Pteroperna plana, *Lyc.*	•	×			small	
Trigonia	•	×	•	•	×	
„ costata, *Sow.*	•	×	•	•	×	
„ elongata, *Sow.*, var. angustata, *Lyc.*	•	•	•	•	×	
„ flecta, *Lyc. & Mor.*	•	×	•	×	×	×
„ Moretoni, *Lyc. & Mor.*	•	•	•	•	×	×
„ n. sp. (allied to T. pullus, *Sow.*)	•	•	•	×		
„ sculpta, var. Rolandi, *Lyc.*	•	•	•	•	•	×
„ scarburgensis, *Lyc.*	•	•	•	•	•	×
„ striata, *Sow.*	•	×	•	•	×	
„ undulata, *From.*	•	×				
Unicardium	•	•	•	•	×	
GASTEROPODA.						
Chemnitzia scarburgensis ?, *Lyc. & Mor.*	•	•	•	•	•	×
„ vittata, *Bean.*	•	•	•	•	•	×
Monodonta	×					
Natica	•	•	•	•	•	×
Nerinæa	•	•	•		×	

FOSSILS.	Great Oolite Series.					
	Upper Estuarine Series.	Great Oolite Limestone.	Great Oolite Clay.		Cornbrash.	
			Survey Collection List.	Mr. Cross's List.	Survey Collection List.	Mr. Cross's List.
CEPHALOPODA.						
Ammonites macrocephalus, *Schl.* (=Harveyi, *Sow.*)					×	×
PISCES.						
Ichthyodorulite (? Hybodus)				×		
Strophodus magnus, *Ag.*					×	
Palate of fish				×		

(5.) Middle and Upper Oolite Fossils.

FOSSILS.	Middle Oolites.				Upper and Middle Oolites.		Kimeridge Clay.							
	Kellaways Rock.	*Lower part of Oxford Clay.	†Upper part of Oxford Clay.	M. S. & L. Railway Cutting.	Cutting N. of Wrawby.	Brickyard ¾ mile N. of South Kelsey Church.	Elsham Cutting.	Claxby Moor Brickyard.	Holton Brickyard.	Moortown Hill Pit.	Pit 1 mile S.W. of Nettleton Church.	Brickyard 1 mile N.E. of North Kelsey.	Worlaby Brickyard.	
ECHINODERMATA.														
Cidaris spinosa, *Ad.*	.	.	.	.	.	.	×							
ANNELIDA.														
Serpula	.	.	.	.	.	×								
„ tetragona, *Sow.*	.	×	×	.	×	.	×	.	.	×	.	×		
„ tricarinata, *Sow.*	.	.	×											
CRUSTACEA.														
Glyphæa	.	.	.	.	×									
BRACHIOPODA.														
Rhynchonella, near to R. oolitica, *Dav.*	.	.	.	.	.	×								
Terebratula ovoides, *Sow.*	.	.	.	.	.	.	.	.	.	.	×			
LAMELLIBRANCHIATA.														
Anomia	.	.	.	.	.	.	?							
Arca	.	.	.	.	.	.	×	.	×					
„ (long sp.)	.	.	.	.	×									
„ (Cucullæa) longipunctata, *Blake.*	.	.	.	.	.	.	×	.	.	×				
Astarte	.	.	.	.	.	.	.	?						
„ carinata, *Phil.*	.	.	.	.	×									
Avicula (like expansa, *Phil.*)	.	.	.	.	.	.	×							
„ inæquivalvis, *Sow.*	.	×	.	.	×	.	×	.	.	×	.	×		
„ Münsteri, *Goldf.*	.	.	.	.	.	.	×							

* Lower part of Oxford Clay includes sections at Black Dyke and Winterton Holme.
† Upper part of Oxford Clay includes sections at 1¼ miles west of North Kelsey Church and Catchwater drain.

FOSSILS.	Middle Oolites.				Upper and Middle Oolites.		Kimeridge Clay.						
	Kellaways Rock.	*Lower part of Oxford Clay.	†Upper part of Oxford Clay.	M. S. & L. Railway Cutting.	Cutting N. of Wrawby.	Brickyard ¼ mile N. of South Kelsey Church.	Elsham Cutting.	Claxby Moor Brickyard.	Holton Brickyard.	Moortown Hill Pit.	Pit 1 mile S.W. of Nettleton Church.	Brickyard 1 mile N.E. of North Kelsey.	Worlaby Brickyard.
LAMELLIBRANCHIATA—*cont.*													
Cardium striatulum, *Phil.*	•	•	•	•	×	•	?						
Ceromya	•	•	•	•	•	×							
Corbula	•	•	•	•	×	•	•	×	•	•	•	×	
Cucullæa	•	•	×	•	•	•	•	•	•	•	×		
Cyprina	•	•	•	•	?		•		•	•			
Cypricardia	•	•	•	•	•	•	•	?					
Exogyra virgula, *Def.*	•	•	•	•	×								
Gervillia	•	•	•	•	•	•	×						
Gryphæa, with markings of Ceromya	×												
„ bilobata, *Sow.*	×												
„ dilatata, *Sow.*	×	×	×	×	×	×							
Inoceramus	•	•	•	×									
„ expansus, *Blake*	•	•	•	•	•	•	×						
Isocardia	•	•	•	•	•	•	•	•	•	•	×		
Leda Phillipsii, *Mor.*	•	×											
Lucina	•	•	•	•	•	•	•	•	•	•	×		
Modiola bipartita, *Phil.*	•	•	•	×	•	•	•	•	•	•		×	
Nucula	•	•	•	•	•	•	•	×	•	×	.		
„ n. sp.	•	•	•	•	×								
„ ornata, *Quenst.*	•	•	•	×	×								
Opis	•	•	•	•	•	•	•	•	•	•	•	×	
Ostrea deltoidea, *Sow.*	•	•	•	•	×	?	×	•	•	×			
„ gregaria, *Sow.*	•	•	•	×									
Panopæa	•	•	•	•	•	•	•	•	•	•	×		
Pecten lens, *Sow.*	•	•	•	•	•	•	×	•	•	×			
Perna	•	•	•	•	•	•	×						
Pholadomya æqualis, *Sow.*	•	•	•	•	•	×	×						
Placunopsis	•	•	•	•	•	•	•	•	•	•	•	?	

* Lower part of Oxford Clay includes sections at Black Dyke and Winterton Holme.
† Upper part of Oxford Clay includes sections at 1½ miles west of North Kelsey Church and Catchwater drain.

FOSSILS.	Middle Oolites.				Upper and Middle Oolites.		Kimeridge Clay.						
	Kellaways Rock.	*Lower part of Oxford Clay.	†Upper part of Oxford Clay.	M. S. & L. Railway Cutting.	Cutting N. of Wrawby.	Brickyard ¼ mile N. of South Kelsey Church.	Elsham Cutting.	Olaxby Moor Brickyard.	Holton Brickyard.	Moortown Hill Pit.	Pit 1 mile S.W. of Nettleton Church.	Brickyard 1 mile N.E. of North Kelsey.	Worlaby Brickyard.
LAMELLIBRANCHIATA—*cont.*													
Posidonomya (?)	•	×											
Thracia depressa, *Sow.*	•	•	•	×	×	×	×	•	×	•	•	•	×
Trigonia	•	•	•	×	×								
GASTEROPODA.													
Alaria	•	•	•	•	•	•	×						
„ trifida, *Phil.*	•	•	•	•	•	×	×	•	•	×	•	×	
Cerithium forticostatum, *Blake*	•	•	•	•	•	•	•	•	×				
„ costigerum, *Piette*	•	•	•	•	×								
CEPHALOPODA.													
Ammonites alternans, *Von Buch*	•	•	•	•	•	•	×						
„ athletus, *Phil.*	•	•	•	×	×								
„ Bakeriæ, *Sow.*	•	•	•	•	×								
„ biplex, *Sow.*	•	•	•	×	?	•	×	•	•	•	×		
„ (near to biplex or rotundus, abnormal form).	•	•	•	•	•	•	•	•	•	×			
„ (near to cymodoce, *D'Orb.*)	•	•	•	•	•	•	×						
„ Kappffii, *Oppel*	•	•	•	•	•	•	×						
„ Koenigii, *Sow.*	•	•	•	•	•	•	×						
„ plicatilis, *Sow.*	•	•	×	•	•	×	?	•	×	•	×		
„ rotundus, *Sow.*	•	•	×	•	×	×	×	×	×	×	•	×	
Belemnites	×	•	•	•	•	•	×						
„ nitidus, *Dolff.*	•	•	•	•	•	•	×						
„ Owenii, *Pratt*	×												
PISCES.													
Fish vertebra	•	•	•	•	•	•	×						

* Lower part of Oxford Clay includes sections at Black Dyke and Winterton Holme.
† Upper part of Oxford Clay includes sections at 1½ miles west of North Kelsey Church and Catchwater drain.

APPENDIX II.

Well Sections and Borings.

*Borings reaching the Keuper.**

Goole Waterworks. Rawcliffe Bridge.

Information supplied to Mr. Cameron by the Clerk of the Works.

	Feet.
Made ground, clay	10
Clay	15
Sand	25

Red Sandstone, encountered at 50 feet from the surface.

There are two 12-inch bores left in the trial holes (two in number) adjacent to the well; in them the water stands at 4 feet from the surface. These bores go down to 50 feet, at which depth the Red Sandstone (Keuper) is reached. It is not at present intended to penetrate further. The water is to be brought to Goole in pipes, laid alongside the Dutch river, to a pumping station.

Mr. Strangways obtained the following information :—

Boring at the New Trent Brewery, Crowle Wharf (Thorne).

	Feet.
Blue clay	60
Rock, water, and alabaster,	2½
Clay	15
Rock	5
Clay	15
Rock	5
Clay	15
Rock	5
Clay	15
Rock	2½
Clay	5
Total depth	145

At this point water rose to within 5 feet of the surface.

Messrs. Strangways and Cameron consider that the uniformity of thickness assigned to the rock and clay beds in this section precludes absolute reliance on the details, though the section is of importance as proving the presence of Keuper Marls as far west as the site of the boring. As, however, the strata in question may be on or about the same horizon, in the lower part of the Keuper Marls, as those in the Clarborough Railway-cutting (Sheet 83), there is nothing very remarkable in the occurrence of shaly sandstones in the Marls at regular intervals.

* For other borings reaching the Keuper Beds see The Geology of the Country between York and Hull (*Mem. Geol. Survey*), 1886.

Wells and Borings in Liassic and Oolitic Rocks.

Record of a boring made on the south side of Bridge Street, Brigg, at a distance of 70 yards west of the River Ancholme, by Mr. Joseph Parker, in 1864–5.

Communicated by Mr. Atkinson, of Brigg.

		Ft.	In.	Ft.	In.
Drift	Vegetable soil and clay, loose	40	0		
Oxford Clay	Blue Shale	42	0		
Kellaways Rock	Sandstone Rock	2	0		
	At this depth (84 ft.) water rose nearly to the surface.				
Oxford Clay	Blue shale	18	0		
Cornbrash	Limestone rock	3	0		
Great Oolite Clay	Blue shale	24	4		
? Great Oolite Limestone	Sandstone rock	0	9		
	Grey shale	1	6		
	Hard rock or boulder	0	6		
	Grey shale	0	11	11	7
	Rock	1	1		
	Unformed rock	6	10		
? Upper Estuarine Series	Grey shale	2	10		
	Sandy shale	10	5	24	2
	Sand (or, ? Hibaldstow beds)	10	11		
Lincolnshire Limestone	Limestone rock	1	8		
	Parting or fissure	0	6		
	Limestone	2	6		
	Parting	0	2	44	7
	Limestone rock	4	6		
	Shale	1	0		
	Limestone rock, with fissures	34	3		
Lower Estuarine beds and Upper Lias	Blue shale	108	5		
Middle Lias	Limestone rock and fissures	11	10		
	Blue shale	21	0		
	Limestone rock	0	6½		
	Blue shale	12	9½		
	Total depth	364	3		

The correlations of the beds given in the above boring are my own, as no other interpretations accord so well with the distribution of the rocks in the district; but I have not ventured to identify the beds below the Lincolnshire Limestone, as it is quite possible that the 108 feet of "Blue Shale" mentioned may include the Lower Estuarine beds, the Upper Lias and Middle Lias Clays, through the omission of mention of the Dogger and Marlstone Rock Bed. On the other hand, 108 feet might represent the Upper Lias alone on this latitude (as it thickens southward). Then the "Limestone rock and fissures" below would be the Marlstone Rock Bed, and the blue shales below Middle Lias with a nodule or impersistent calcareous band of 6½ inches.

Boring for Ironstone, by the Railway, at half a mile south-west of Scawby Station.

Communicated by Mr. Charles Hett, A.M.Inst. C.E., of Brigg.

	Ft.	In.	
Limestone	5 feet to 6	0	[Hibaldstow Beds.]
Clay	4	0	Kirton Beds.
Rock	2	0	
Clay	9	0	
Rock	1	0	
Clay	18	8	
Rock	1	6	
Clay	2	5	
Rock	11	0	
Clay	57	0	? Lower Estuarine.
Stone	1	0	? Upper Lias.
Shale	92	6	
Rock very hard (probably Ironstone)	7	0	? Marlstone Rock Bed.

The want of detail in this boring forbids the correlation of the beds with any degree of certainty. It is probable that limestones occur in the 18 feet 8 inches of clay, as such a development in the Kirton Beds is quite abnormal. The Upper Lias may also include a considerable part of the 57 feet of clay, unless the latter represents clayey Kirkton Beds as well as Lower Estuarine clays, mention of stony bands being omitted.

Well at Mr. Foster's, the new house at the turning from the Brigg and Hibaldstow road to Castlethorpe.

Communicated by Mr. Cressey, well sinker, Scunthorpe.

	Ft.	In.
Yellowish brashy stone	7	0
Clay	4 ft. to 5	0
Dark blue stone.		
Hard limestone.		
The top bed is the base of the Hibaldstow Beds.		

The following borings, 1 to 4, were communicated to me by Mr. Atkinson; they were subsequently furnished to Mr. Strangways by the Rev. J. E. Cross, with others, which are given further on. We commence with Bore 3, in the Oolitic area, south of Appleby Station, as its site, Spring Wood Lodge, is shown on the Ordnance Map, and the positions of the other three borings are indicated with reference to it. The correlations are my own; from the Dogger downward they are tolerably certain.

Bore 3. At Spring Wood Lodge.

			Ft.	In.
Lincolnshire Limestone.	There being no surface deposits at this spot Oolitic limestone is no doubt thus described.	Gravel (round limestone) and sand	18	0
		Red sand (possibly Lower Estuarine)	10	4
Probably Lower Estuarine		Blue shale	24	0
Dogger		Stone, very hard	1	3
Upper Lias		Dark blue shale	37	6
Middle Lias	Marlstone Rock Bed.	Sandstone (Northampton bed)	5	4
	Clay	Blue shale	68	2
	Pecten bed	Ironstone top bed	4	2
Lower Lias	Clay	Blue Lias shale	89	9
	Frodingham Ironstone	Ironstone bottom bed	24	3

Bore 4, 1 mile and 54 chains north of Bore 3.

			Ft.	In.
Lincolnshire Limestone -	Limestone - -		36	8
Probably in part Lower Estuarine.	Blue shale - -		34	4
Dogger - - - -	Sandstone - -		1	11
Upper Lias - - -	Grey shale - -		25	10
Middle Lias: Marlstone Rock Bed.	Sandstone (Northampton bed) - -		7	10
Middle Lias: Clay - -	Shale, with cement nodules - -		67	6
Middle Lias: Pecten bed -	Ironstone top bed -		4	2
Lower Lias: Clay - -	Blue Lias shale - -		89	9
Lower Lias: Frodingham Ironstone.	Ironstone bottom bed -		24	3

Bore 1, 2 miles due west of Bore 3.

	Ft.	In.
Sand - - - - - - - -	1	4
Ironstone (Frodingham rock) - - - -	18	5

Bore 2, 1 mile and 2 or 3 chains due west of Bore 3.

	Ft.	In.
Sand - - - - - - -	3	0
Lower Lias: Blue Shale - - - -	78	0
Lower Lias: Ironstone - - - -	30	0
Lower Lias: Blue Shale - - - -	5	0

Bore 1 is of no value, but in Bore 2 we have the Frodingham Ironstone penetrated, and its relations to the Lower Lias above and below, exceptionally shown.

Mr. Strangways furnishes the following notes:—

There are nine sections (boreholes and shafts) nearly in a straight line, between the Keeper's Lodge at Spring Wood and Appleby.* These sections, although tolerably clear for the divisions of the Lias, are not so for the Oolites above, probably from the fact of the very shaly character of much of the limestone which in these accounts seems to have been frequenfly entered under the name of "bind."

The following sections are also in these beds:—

Boring at Roxby.

	Ft.	In.
Rock (limestone ?) - - - - -	4	0
Measures to blue clay - - - - -	40	0

Well at Roxby Grange.

	Ft.	In.
Soil - - - - - - -	2	0
Gravelly stuff (probably broken rock) - - -	9	0
Shale - - - - - -	4	0
Grey stone, very hard - - - - -	0	6
	15	6

* The Rev. J. E. Cross very kindly procured these sections for us. They were made by Mr. Wian (to whom we are indebted for permission to publish them), in order to prove the depth and nature of the Lias Ironstones.

The Parsonage well on the opposite side of the stream is very similar to this last.

High Risby.

Well 15 yards all rock (limestone and greystone).

Roxby.

	Ft.	In.
Limestone	2	0
White and red sand	16	0
	18	0

Winterton.

Well 16 yards (limestone, thin greystone, and blue shale).

C. F. S.

The four borings given under, viz., two at Haverholme Plantation and North and South Shafts Appleby, were furnished to Mr. Strangways by the Rev. J. E. Cross.

The correlations are mine; but in the North and South (Appleby) Shafts from the Middle Lias upward it is impossible to be certain as it is probable that the junctions between Upper Lias, Lower Estuarine Series and Kirton Beds occur in the items mentioned, and so could not in any case be severally bracketed. The mention of sand and gravel in the upper beds may be due to oolitic limestones being misinterpreted, as at Spring Wood Lodge.

W. A. E. U.

Borings at Haverholme Plantation.

Due north of the Spring Wood Lodge Boring.

A.—5½ furlongs N. of Spring Wood Bore.

		Ft.	In.
	Sand	7	0
	Limestone	40	6
? Lr. Estuarine	Shale	7	0
? Dogger	Limestone	4	4
? Upper Lias	Shale	15	6
Middle Lias	Limestone	6	7
	Blue shale	60	5
	Ironstone	3	5
	Blue shale.		

B.—7 furlongs N. of Spring Wood Bore.

	Ft.	In.
Cornbrash limestone	4	0
Sandstone, Shale, White sand, Clays	78	9
Limestone (not bored through)	43	3

In Boring B. the beds under the Cornbrash are evidently given in so generalized a way that no correlation of Great Oolite Clays and Hibaldstow Beds could be attempted. The 60 feet of "Blue shale," in Bore A., appears to be Middle Lias, and the shale 15 feet 6 inches thick may be the sole representative of the Upper Lias.

Detailed account of the South Shaft, Appleby.

	Ft.	In.	Ft.	In.
Earth	0	8		
Yellow sand	4	6		
Grey sand	2	0	10	2
Gravel	2	0		
Grey sand	1	0		

Detailed account of the South Shaft, Appleby—*continued.*

		Ft.	In.	Ft.	In.
	Blue clay	1	0		
	Gravel	2	0	7	0
	Blue clay	2	0		
	Gravel	2	0		
	Limestone	2	6		
	Blue bind	0	6		
	Blue limestone	1	0		
	Blue bind	0	10	11	10
	Strong blue limestone	2	6		
	Strong bind	1	6		
	Blue bind	0	6		
	Strong blue limestone	2	6		
	Strong bind	3	0		
	Blue bind	5	0		
	Strong bind	3	0	16	0
	Stone	4	6		
	Blue bind	0	6		
	Strong blue limestone	4	6		
	Clay parting	0	2	6	8
	Strong blue limestone	2	0		
? Lower Estuarine and Dogger.	Stone bind	4	8	10	8
	Blue bind	6	0		
	Ironstone	1	1	4	1
	Sandstone with iron	3	0		
? Upper Lias.	Blue bind	12	0		
	Blue bind	17	0		
	Strong blue limestone	1	0	69	4
	Blue bind	38	0		
	Strong bind	1	4		
? Marlstone Rock Bed.	Strong stone	5	6	7	0
	Stone mixed with sulphur and coprolites	1	6		
		142	9		

Detailed account of the North Shaft, Appleby.

		Ft.	In.	Ft.	In.
	Earth	0	9		
Lincolnshire Limestone.	Limestone gravel	7	0		
	Yellow limestone	4	3		
	Blue limestone	4	0		
	Strong blue limestone	3	0	26	2
	Clay parting	0	2		
	Strong blue limestone	3	0		
	Blue bind	0	9		
	Strong blue limestone	3	3		
	Strong blue bind	2	0		
	Stone bind	2	8	12	2
Correlation very uncertain.	Blue bind	6	0		
	Yellow bind	1	6		
	Blue bind	27	0		
	Blue limestone	1	0		
	Blue bind	2	0	87	0
	Strong bind	3	0		
? All Upper Lias.	Blue bind	54	0		

Detailed account of the North Shaft Appleby—*continued.*

			Ft. In.	Ft. In.
Middle Lias	Marlstone Rock Bed.	Strong stone	5 6	7 0
		Stone mixed with coprolites and sulphur.	1 6	
	Clay	Blue bind	63 0	
	Pecten Bed	Ironstone (Pecten)	4 10	
Lower Lias Clay		Blue bind	93 0	
Frodingham Ironstone.		Top of Ironstone (Scunthorpe low bed).		
			293 2	

Wells and Borings in the Wolds.

Cabourn.—At the farm 1 mile north-east of the Church. Information supplied to Mr. Clement Reid by Mr. Hopkins.

	Feet.
Chalk, to gravel (Carstone)	162

Swallow.—At the farm 1 mile north-west of the Church. Information supplied to Mr. Clement Reid by Mr. Hopkins.

	Feet.
Chalk, becoming red	174
Gravel, as bright as glass (Carstone)	1
	175

Supply of water very limited and soon exhausted by pumping.

Rothwell.—At the farmstead one mile E.N.E. of the Church. Information obtained from the foreman by Mr. A. J. Jukes-Browne, and from specimens on the spot.

	Feet.
Soil and earth	4
Gravel of small chalk pebbles	16
Clean red clay	1
Small pebbly sand / Hardstone rock } Carstone	8
	29

Wells and Borings in Superficial Deposits.

Ancholme valley.—Wells sunk on Broughton Carrs, three-quarters of a mile south-east of the Old Decoy, 50 yards apart. Information supplied by Mr. Cressey, of Scunthorpe, Well-sinker, to Mr. Usher.

	Ft. In.
Top Peat	0 9
Blue clay	20 0
Tough, light-coloured, silty clay, about	6 0
Harder clay, rather peaty	5 0
	31 9
Peat	0 9
Blue clay	21 0
Gravel (spring)	8 0
	29 9

South Kelsey, at the Bull Inn, near the Church. Communicated by the landlord, Mr. Boorne, to Mr. A. J. Jukes-Browne.

	Feet.
Soil	2
White clay (Boulder Clay)	16
Fine yellow sand	6
	24

Humber Valley.:—Humber Bed, between Hessle and Barton.*

Borings made for the North-Eastern Railway.

Communicated by Mr. Kelsey to Mr. Clement Reid.

No. 2 bore-hole, 300 yards east of Hessle Ferry. (Commences at level of high water.)

	Feet.
Yellow clay	6
Light-coloured warp clay	7
Soft dark warp clay	7
A little stronger warped	5
Dark peat	7½
Clay and Gravel	2½
Pebbles and flinty Gravel	3½
Light-coloured warp	2
Fine sand and loose Chalk	2
To Chalk	42½
Red-coloured loose Chalk	7½
White Chalk and flint	16
	66

No. 3 bore-hole, 7 chains south of No. 2, and immediately within the Humber bank. (Commences at level of high water.)

	Feet.
Yellow warped clay	7
Black silty warp	16
Blue warp and turf	11
Yellow warp	4
Warped Chalk, gravel, and flint	6
To Chalk	44
Red coloured Chalk	10
White Chalk and flint, full of water	14
	68

* These borings are reproduced from the Geology of Holderness. (*Mem. Geol. Survey*), pp. 151–153.

No. 4 bore-hole, 10 chains south of No. 3 (in 26 feet of water).

	Feet.
Peat	1½
Blue warp and peat	3
Yellow clay	10½
Fine gritty Chalk and sand	½
Yellow warp	2
Yellow sandy warp	4
Sand, pebbles, and loose Chalk	3
To Chalk	24½
White Chalk and flint, full of water	30
	54½

No. 8 Bore-hole, 10 chains south of No. 4 (in 33½ feet of water).

	Feet.
Black warped sand	19
Warped sand and gravel	3
To Chalk	22
Loose yellow Chalk and flint	8
White Chalk and flint	9
Very soft Chalk	6
White Chalk	6
	51

No. 7 bore-hole, 8 chains south of No. 8 (in 33 feet of water).

	Feet.
Fine Sand, to Chalk	23
Loose Yellow Chalk	9
White Chalk and flint, full of water	16
	48

No. 11 bore-hole, 12 chains south of No. 7 (in 36½ feet of water).

	Feet.
Fine quick boiling Sand	18
Dark loamy Sand	9
To Chalk	27
White Chalk, full of water	4
	31

No. 9 bore-hole, 12 chains south of No. 11 (in 39 feet of water).

	Feet.
Quick boiling sand	25
Dark loamy sand	10
To Chalk	35
Chalk, full of water	4
	39

No. 10 bore-hole, 17 chains south of No. 9 (in 27½ feet of water).

	Feet.
Fine light sand	25½
Coarse dark sand	22½
To Chalk	48
White Chalk	3
	51

No. 12 bore-hole, 26 chains south of No. 10 (in 24 feet of water).

	Feet.
Loamy sand	25
Coarse sand and Gravel	11
Sand, coarse Gravel, and Chalk pebbles	5
To Chalk	41
White Chalk	5
	46

No. 6 bore-hole, 10 chains south of No. 12 (in 25½ feet of water).

	Feet.
Sandy warp	7
Strong marl	10
Fine Sand, full of water	25
Soft red clay	2
Sand and Gravel	4½
Strong marl [Boulder Clay]	7
Gravel	3
Chalk not reached at	58½

No. 5 bore-hole, 22 chains south of No. 6 and immediately within the Humber bank about ¾ mile east of Barton Water Side (commences on the warp about 3 feet below high-water level).

	Feet.
Red clay	8½
Peat	3
Coarse sand	20
Strong clay, small chalk stones [Boulder Clay]	8
Soft warp	28
Strong fine clay	5
Chalk not reached at	72½

Boring at Reeds Island in the Humber. Information supplied by Mr. Owston to Mr. Strangways.

	Ft.	In.
Warp to bed of the Humber	90	0
Black clay	3	0
White sand	7	0
Blue clay	5	0
Gravel	13	0
Soft clay	15	0
Fine clay	27	0
Ironstone	25	0
White Chalk	7	0
	192	0

The water rose 2 feet 10 inches above the surface.

Trent Valley:—The following accounts of three wells in the Alluvium on the east of the Trent were furnished by Mr. Cressy, well-sinker, Scunthorpe, to Mr. Ussher:—

Well at the Inn at Gunhouse Wharf.

	Ft.	In.
Strong warp	10	0
Clay	3	0
Silty warp	14	0

Well on the south-east of Neap Ho.

Sand bed Peat, about 2 feet Sand, 8 or 9 feet	11 feet.

Well at the cross roads by the new house on Brumby Common.

	Feet.
Sand	30
Peat bed	about 20 ?
Clay (not penetrated in sinking)	about 20

Mr. Cameron supplies the following accounts of Althorpe and Gunthorpe (near West Stockwith):—

Althorpe Wells, old name Aletorp.

	Feet.
Warp	8 to 10
Sand	2
Warp.	

Gunthorpe.—The relation of the surface deposits as seen in drains appears to be:—

Warp	1 ft. to 15 ft.
Peat	6 in. to 5 ft.

Clay or Warp below again sometimes, but oftener sand.

Hard water, furring kettles, so that Trent water is preferred and greatly used.

Well-sections, &c. in the northern part of Sheet 86 (*N. of the Humber*).—Several borings, &c., are given in the "Geology of the Country," between York and Hull. *Mem. Geol. Survey*, 1886. The following is a list of those not printed in this memoir:—

Barnsby on the Marsh, p. 43, 47.
Barnsley Bridge, p. 5.
Eastrington, p. 43.
Ferriby, p. 45.
Goole, p. 5–7.
Hessle, p. 45.
Howden, p. 44.
Hull Waterworks Tunnel.
Melton Creek, p. 45.
Reedness (on south bank of Humber), p. 7.
Staddlethorpe, p. 43.
Thimble Hall, p. 44.
Walling Fen, p. 47.
Welton, p. 45.

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Clee Hill, 53 (NE, NW).
Flintshire and Denbighshire, 74 (NE & SE), 79 (NE, SE).
Derby and Yorkshire, 71 (NW, NE, & SE), 82 (NW & SW), 81 (NE), 87 (NE, SE), 88 (SE).
Forest of Dean, 43 (SE & SW).
Forest of Wyre, 61 (SE), 55 (NE).
Lancashire, 80 (NW), 81 (NW), 89, 88 (SW, NW).
Leicestershire, 71 (SW), 63 (NW).
Northumberland & Durham, 103, 105, 106 (SE), 109 (SW, SE).
N. Staffordshire, 72 (NW), 72 (SW), 73 (NE), 80 (SE), 81 (SW).
S. Staffordshire, 54 (NW), 62 (SW).
Shrewsbury, 60 (NE), 61 (NW & SW).
South Wales, 36, 37, 38, 40, 41, 42 (SE, SW).
Warwickshire, 62 (NE SE), 63 (NW SW), 54 (NE), 53 (NW).
Yorkshire, 88 (NE, SE), 87 (SW), 92 (SE), 93 (SW).

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